EUROPEAN COMMISSION
DIRECTORATE GENERAL JRC
JOINT RESEARCH CENTRE - ISPRA
Institute for the Protection and Security of the Citizen
Agriculture and Fisheries Unit

JRC IPSC/G03/P/PSP/psp D(2005)(5091) /

Publication EUR21888 EN

processing VHR satellite imagery in Tsunami affected areas of Indonesia and Sri Lanka

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Date:	28/11/2005	***Int. ref:***	file://S:\FMPArchive\P\5091.doc

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EUR 21888 EN
Luxembourg: Office for Official Publications of the European Communities

1. Introduction

1.1. objectives

1.1.1. The content of this publication forms part of the post-tsunami assistance package financed under the European Commission and which is being implemented by the JRC (Joint Research Centre) on behalf of DG Relex. In this scope the European Commission, together with the Indonesian and Sri Lankan Authorities, had identified earlier the need to provide the above mentioned Authorities with very high resolution satellite imagery of the affected coastline before and after the December 2004 tsunami. The availability of such imagery, transformed to 1/5000 scale baseline image maps will help the authorities in precise damage assessment, elaborating reconstruction plans and risk analysis.

1.1.2. In this context, two times a 2-week mission was carried out in order to deliver the above mentioned imagery and above all to start the ortho-rectification process together with the national authorities of both Sri Lanka and Indonesia. Capacity building of the local staff in processing raw imagery (ortho-rectification), in land surveying using DGPS techniques and in different aspects of GIS guidance the was considered as essential.

1.2. Project description related to JRC Technical Support

1.2.1. Key deliverables :

- management of procurement of pre- and post-tsunami very high resolution satellite imagery,
- Assistance in ortho-rectification processes
- DEM and GCP selections
- delivery of satellite imagery to national authorities
- provision of basic technical assistance to the concerned national authorities to help with the start up of the use of these data at appropriate processing for baseline mapping and trouble shooting.

1.2.2. During the missions mentioned above JRC brought own Hardware as well as software and DGPS receivers to be able to work fully independent.

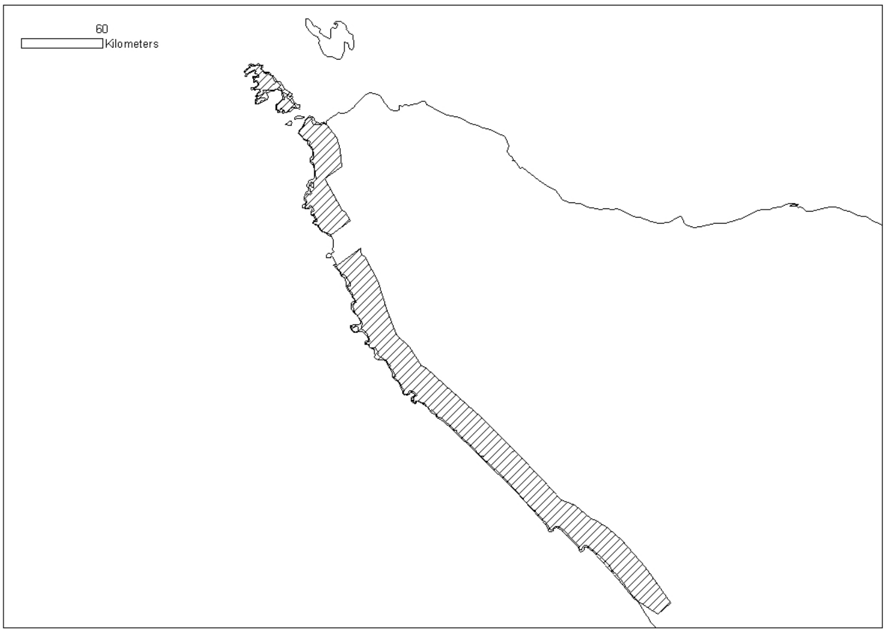
- Hardware
  - Laptop and external harddisk with 500 Gbyte capacity
- Software
  - ArcGIS, PCI gematics 9.1 Prime, Erdas imagine 8.7, Ashtech Office suite and Trimble office for GPS postprocessing
- GPS instruments

- o 2 Trimble 5700 series (dual frequency carrier- phase receivers) with software, antennas and cabling.

2. Indonesia and Sri Lanka VHR imagery deliverables

2.1. Area of interest (Indonesia)

2.1.1. The area of interest defined by the Indonesian authorities consisted of a coastal strip 10 km wide, in total 2445 km^2. This area was evaluated with respect to image availability either pre-Tsunami or post-Tsunami. Both sets of data are required to assist the reconstruction phase. It is evident that only imagery available in the image providers' archives can be used for pre-Tsunami coverage; whereas imagery for post-Tsunami cover may consist of either archived data, or data that is newly acquired.

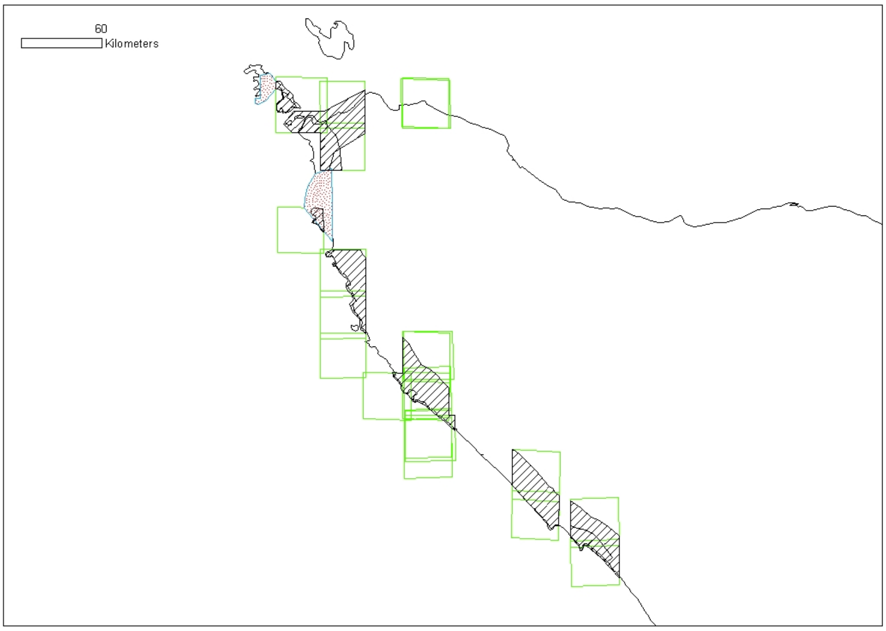


2.2. Delivered pre-tsunami imagery (Indonesia)

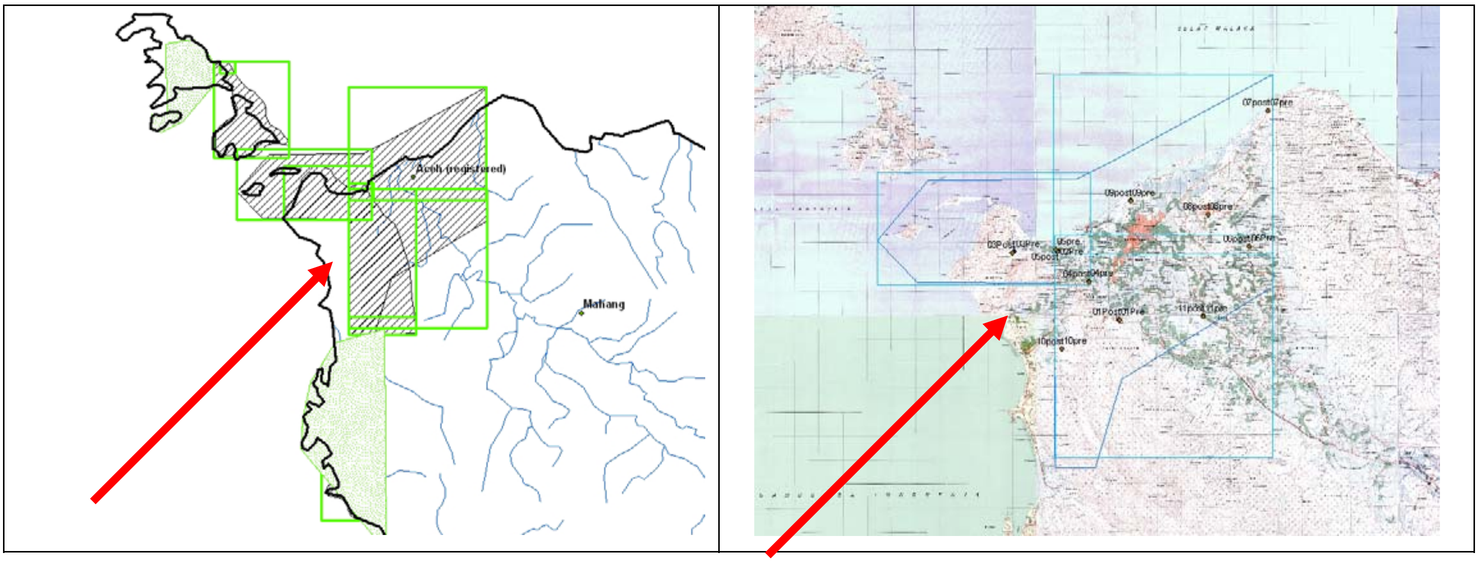
2.2.1. All imagery delivered so far[1] comes from the Quickbird satellite. A total area of 1230 Km^2 **Quickbird** imagery has been delivered, that is all the imagery available from the image provider's archive. In order to have a maximum area covered, we went back in the archive until 2002.

2.2.2. There are two further areas of interest (red dashed areas on the map below, with areas 184km^2, 50km^2) covered by IKONOS satellite imagery; these images still have to be delivered to BPN.

[1] For a list of delivered PRE tsunami images see **annex 1**



2.2.3. The Loghna area (south of Banda Aceh) is, together with the other regions very important for the reconstruction and owners' registration of their properties. This community had 24 villages destroyed by the disaster. Survivors were extremely disappointed that there was no imagery available. These people want to start reconstructing but without Pre-tsunami ortho-rectified imagery there is no way to find back the properties on the terrain. This area (56km^2) was included in the area of interest. However, the scenes covering this specific area did not met the original cloud cover criteria which is set on a max cloud cover of 20%.



2.2.4. We have therefore asked the image provider to double check the archive and they have found one image with a lot of cloud-cover. With some filtering, this could be used, and will be included in future deliveries to the BPN.

2.3. Delivered post-tsunami imagery (Indonesia)

2.3.1. An almost complete coverage (see diagram below, a list of delivered post tsunami imagery is given in **annex 1**) of the affected area has been delivered to BPN. One small area of interest (115km^2) which has not yet been acquired will be delivered to BPN as soon as JRC has received the data from the image provider.

2.3.2. The entire area of interest, including the area not yet acquired, covered by post-tsunami imagery equals 2445 Km^2.

2.4. Area of Interest. (Sri Lanka)

2.4.1. The area of interest defined by the Sri Lankan authorities consisted of a coastal strip 10 km wide, in total 11792.55 km^2. This area was evaluated with respect to image availability either pre-Tsunami or post-Tsunami. Both sets of data are required to assist the reconstruction phase. It is evident that only imagery available in the image providers' archives can be used for pre-Tsunami coverage; whereas imagery for post-Tsunami cover may consist of either archived data, or data that is newly acquired.

2.5. Delivered Pre tsunami imagery (Sri Lanka)

2.5.1. For purchasing as much pre tsunami imagery available in the archive of the 2 image providers, we went back as far as 2000. This resulted in 8180 km^2 IKONOS imagery and 5567 km^2. South of the island there is a small area missing due to unsuitable image quality (due to persistent cloud cover).

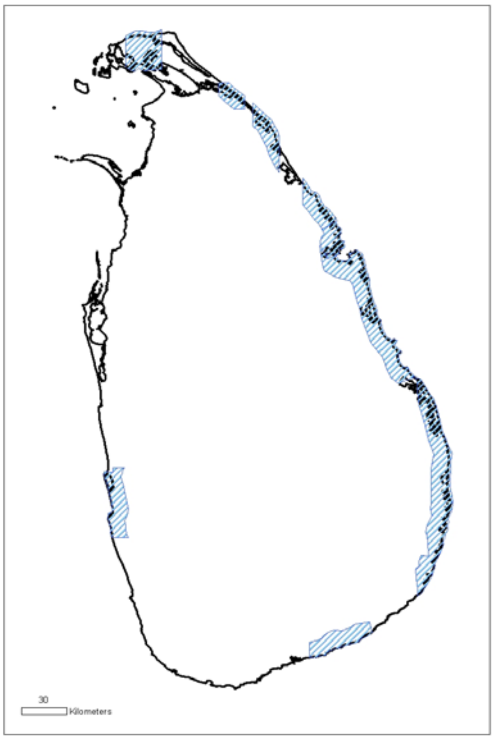
2.6. Post Tsunami imagery in tasking (Sri Lanka)

2.6.1. A complete coverage of the entire coastline is currently underway and will be finalised before the end of the year (weather permitting). The weather-conditions for the last months were not much in favour for image acquisition. Therefore, only a part on the east coast has been delivered so far; this imagery is entirely from the QuickBird sensor.

2.6.2. Foreseen area to be purchased by IKONOS = 7823 km^2, for QuickBird the total area = 6435 km^2.

2.7. Delivered Post tsunami imagery. (Sri Lanka)

2.7.1. On the moment of the reporting (date 15 September 2005) a total of 9 areas of interest have been delivered, mostly located at the east of the island (thus the most affected area), corresponding to a total of 5448 km^2.



2.8. Image server

2.8.1. The South-East Asia image browser is a web based application allowing for visualization of all VHR images acquired over Sri Lanka under the scope of the Rapid Reaction Mechanism. It is based on a map-server (free software developed by the developers community and initiated at University of Minnesota) and the map-server framework p-mapper (available at www.sourceforge.net).

2.8.2. All data have been automatically preprocessed using IDL/ENVI for display in the SE-Asia image browser as follows:

- Quickbird raw images have been mosaicked together when delivered in tiles, then the mosaic has been automatically histogram stretched to byte and compressed into ECW format (a wavelet compression format).
- Ikonos raw images have been histogram stretched to byte and compressed into ECW.
- Images are then displayed as a mosaic in the SE-Asia image browser, all images being on the fly re-stretched from 3 to 255 to avoid all black and near-black parts.

2.8.3. The link to the Web Map Browser is as follows: http://marsmap.jrc.it/browsers/se-asia/start.html. [2]

[2] The web browser is password protected. For access please contact Paul.hasenohr@jrc.it or peter.spruyt@jrc.it

3. Execution Indonesian Project

3.1. Kick of meeting and visit to photogrammetric department BPN

3.1.1. The kick-off meeting was led by Dr Pak Pelopor who is the BPN manager for the reconstruction of the Banda Aceh region project (RALAS). Mr. Tri, manager of the photogrammetric department, and two of his surveyors also participated.

3.1.2. More or less 600,000 parcel properties are to be reconstructed. In Banda Aceh region only 27 % of the properties have been registered pre-tsunami. Of these, only 80% have hard copy data. Moreover, this hard copy data was severely damaged and is now in the process of restoration attempts.

3.1.3. According to Mr Tri of the photogrammetric department, no airborne data is available, nor digital elevation models. Therefore the only hope and solution in order to have information on properties for the above mentioned region is via Very High Resolution satellite imagery.

3.1.4. It is stated that it is therefore extremely important that an accurate ortho-rectification takes place with a RMSE in one dimension of less then approximately 2 meters. It is foreseen that not only ground control will be used but also a number of checkpoints will be measured in order to have an exact idea of the geometric quality of the end product.

3.1.5. A presentation has been given by PS in order to show the geometric potential of VHR when a correct ortho-rectification has been executed.

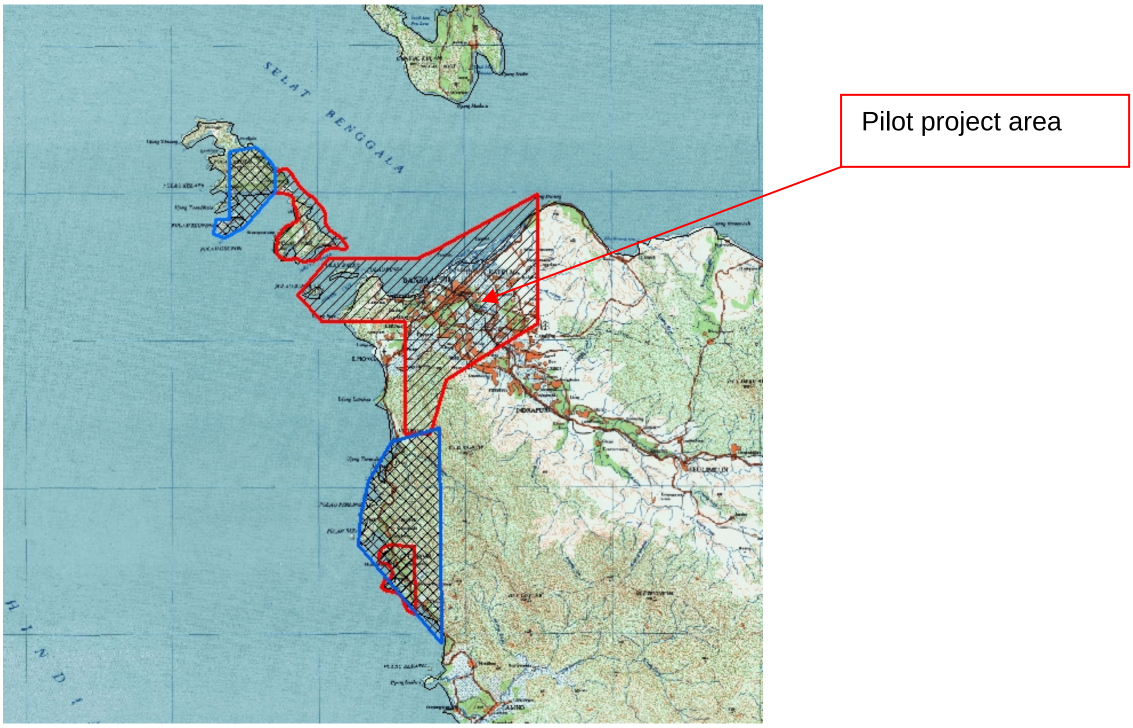
3.1.6. A triangulation network in the Banda Aceh region has been established by the directorate of surveying and mapping. This has been done with DGPS dual frequency instruments. This network can be used for reference position of our DGPS equipment.

3.1.7. Using this triangulation network as a base, some Ground control points have been measured by the BPN surveying team. In Banda Aceh 10 points have been acquired, while in Meulaboh some 6 points are available

3.1.8. In order to perform a correct ortho-rectification of VHR satellite imagery we need to have high accurate points. But it is highly unlikely that we will find the measured points on the image. In the case we find them then the rectification can take place straight away. Once rectified a visit to BA is foreseen in order to measure Checkpoints. In the case that GCP’s cannot be found back, a visit to BA is foreseen as soon as possible to measure GCP’s and Checkpoints.

3.2. Pilot PROJECT Banda Aceh (Indonesia)

3.2.1. In order to transfer know-how and perform capacity building of the BPN staff in Banda Aceh it was decided that we would work on a pilot project PRE tsunami, in which all necessary steps to perform a correct state of the art ortho-rectification would be explained and executed.



3.2.2. The pilot zone covered the main urban area of Banda Aceh. This zone was chosen as a pilot because of an existing geodetic network. Furthermore, this zone considered as one of the most important areas for the reconstruction project RALAS, together with the Meulaboh area. The pilot project Banda Aceh Pre tsunami is covered by 3 scenes. (see annex 1, imageorder 193049).

3.2.3. The terrain can be considered as flat, with some hilly parts on the east of the area.

3.3. Ground control

3.3.1. To perform a correct ortho-rectification using the RPC function we need to have accurate ground control, a digital elevation model and the raw uncorrected image. The ground control data measured by BPN Jakarta were insufficient, only 2 GCP's of the 10 measured were found back on the image with confidence. Therefore, a Differential GPS (DGPS) campaign was prepared.

3.3.2. After 1.5 days of training the team was independent and performed a 1 day field trip with the equipment with 100 % success. During the 1.5 days training and the 1 day independent measurement by the officials of BPN Banda Aceh, a total number of 8 high precision ground control points was measured.

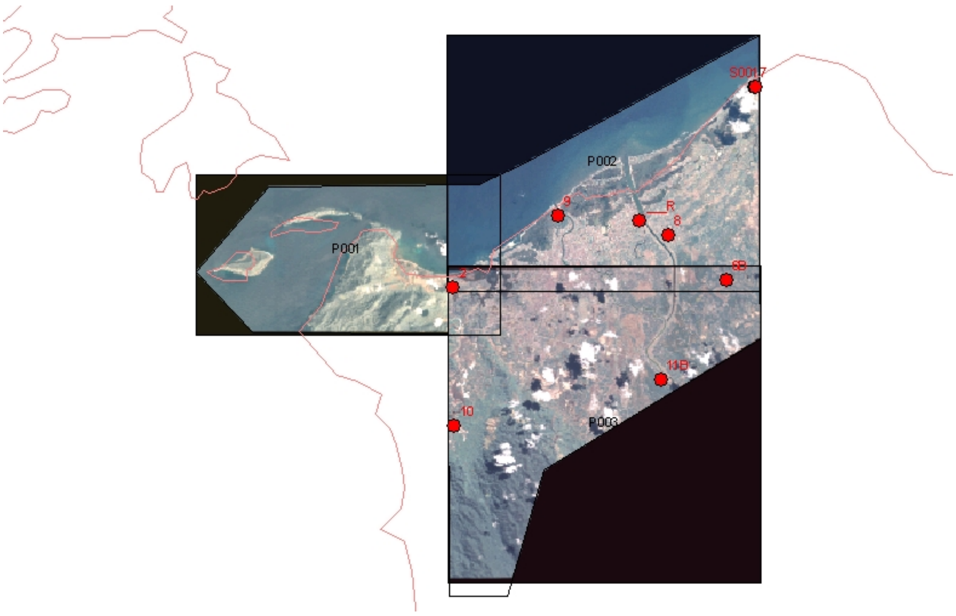
GPS team learning the functions of the Trimble GPS controller

3.3.3. The selection of the ground control points to be measured is extremely important for the final geometric result of the rectification. We spent therefore some time in order to find the best possible points to be measured in the field.(for a detailed description of the points see **annex 2**)

3.3.4. Measured ground control over the test area:

- One of the geodetic points part of the network has been used as base-station or reference point. The location of this point is situated on the parking-lot of the BPN offices. The geodetic point is materialized by the geodetic service with a blue painted block in concrete. Embedded in that block is the precise position of the geodetic point (see pictures below). The name of the geodetic point in question = S01.015

- The pilot area is covered by 3 satellite image scenes. In each scene we tried to measure 4 points. The scene p002 and P003 did not pose any problem. In scene p001 however we only could measure only 1 point due to access-problems of the area.



- The result after post-processing the GPS measurements is shown in the table below. The coordinates listed below are in the projection system UTM (universal transverse mercator) using zone 46 North and with the Ellipsoid WGS84. The absolute precision of these points is cm accurate with respect to the reference geodetic point.

Point Number	X (m)	Y (m)	Ellips. Height [m]	Orthom. Height [m]
R	760928.04	616832.35	-32.91	2.71
7	767043.48	623981.06	-29.61	5.67
8	762461.27	616030.10	-31.46	4.04
6B	765582.18	613614.14	-30.33	4.94
11B	762070.11	608296.87	-27.80	7.73

S001	767121.10	623960.59	-26.98	8.29
10	750981.21	605833.54	-34.18	2.33
2	750917.09	613265.48	-33.05	3.42
9	756528.96	617091.31	-33.80	2.17

3.3.5. A number of initially selected points could not be measured due to access problems. Note that the area outside the urban area can be rather dangerous due to active military groups

3.3.6. At the end of the measurement campaign the GPS team was very confident with the GPS equipment. For a detailed description of the GCPs see **annex 2**.

3.4. Digital elevation model

3.4.1. Although the pilot area is mostly flat, a digital elevation model (DEM) must still be used in order to have no risks in the quality of the ortho-rectification.

3.4.2. The DEM used is the SRTM (The Shuttle Radar Topography Mission) [3] 3-arcsec. Data studies in the JRC[4] have shown that most of the SRTM data has a geometric quality of better than 5m RMSE, suitable for the task.

3.4.3. Using the accurate ground control points measured using DGPS, we can perform a geometric quality control of the digital elevation model. Note that the elevations are orthometric height above the WGS84 ellipsoid.

PtNr	*Height GPS [m]*	*Height DEM (m)*	*Dz*	*Dz^2*
___R	2.713	3	-0.3	0.08
7	5.668	7	-1.3	1.77
8	4.035	9	-5	24.7
6B	4.938	6	-1.1	1.13
11B	7.731	8	-0.3	0.07
S001	8.289	10	-1.7	2.93
10	2.327	6	-3.7	13.5
2	3.42	6	-2.6	6.66
9	2.174	2	0.17	0.03
		RMSEz =		2.38

3.4.4. This resulted in an RMSEz of the Digital elevation Model used for the ortho-rectification of 2.38 m, confirming the JRC results assessed elsewhere, and very suitable for performing an accurate ortho-rectification.

3.4.5. The complete DEM has been delivered to BPN in order to ortho-rectify the remaining areas.

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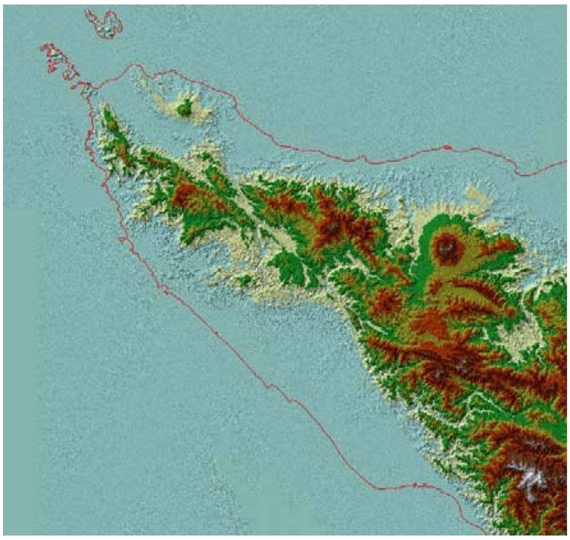
3 http://www2.jpl.nasa.gov/srtm

4 Study by Rafal Zielinski "Quality elevation of SRTM basic DEM" Internal JRC document file://S:\FMPArchive\P\3371.doc. For a copy contact peter.spruyt@jrc.it



4. Execution Sri LANKAN project

4.1. Meeting Delegation European Commission

4.1.1. The meeting was held in the office of the delegation of the European Commission in Colombo.. Delegation officials and officials from UDA (Urban Development Authority) Office of the President, Universities, survey department and Sri Lanka Navy participated the meeting.

4.1.2. An overview has been given of the imagery delivered and the imagery still in tasking. This has been done by using an internet-connection to access the image server mentioned in paragraph 2.5

4.1.3. It is stated that it is extremely important that an accurate ortho-rectification takes place with a RMSE in one dimension of less than 2 meters. It is foreseen that not only ground control will be used but also a number of checkpoints will be measured in order to have an exact idea of the geometric quality of the end product.

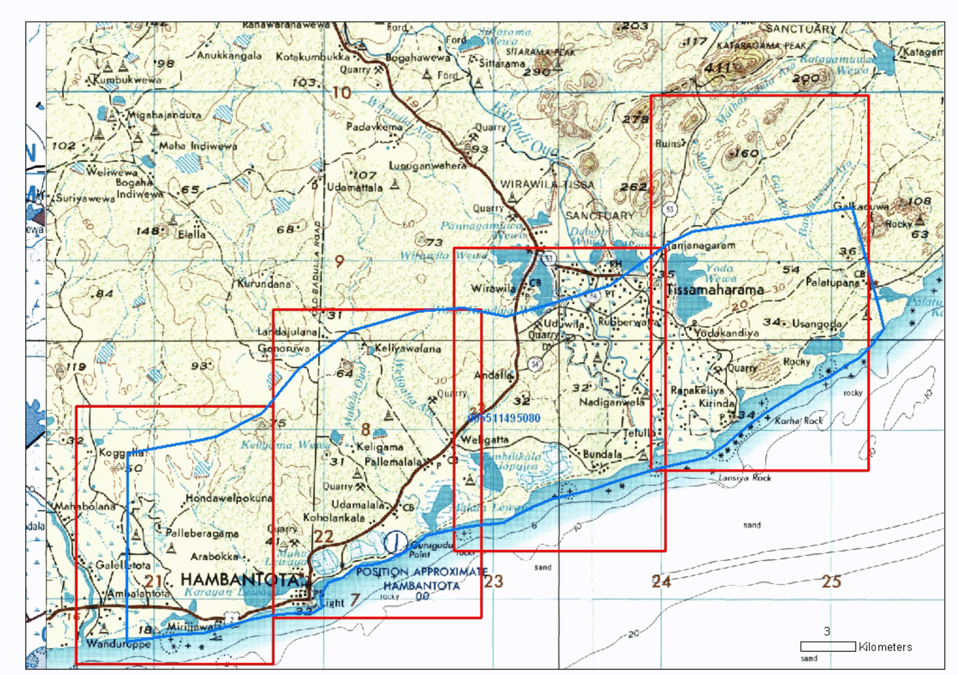
4.1.4. A presentation has been given by PS in order to show the geometric potential of VHR when a correct ortho-rectification has been executed.

4.1.5. Outline of the pilot-project in Hambantota have been discussed and approved.

4.2. Pilot project Hambantota (Sri Lanka)

4.2.1. In order to transfer know-how and perform capacity building of the UDA staff in Colombo it was decided that we would work on a pilot project PRE and POST tsunami, in which all necessary steps to perform a correct state of the art ortho-rectification would be explained and executed. In collaboration with the UDA staff the area of Hambantota was selected.

4.2.2. The location of the Pilot area is south of Sri Lanka around 180 Km from Colombo. In Sri Lanka this means around 6 hours driving. The pilot area covered 4 Pre tsunami Ikonos scenes and 1 big quickbird post tsunami image.



4.2.3. **Pre tsunami imagery** over the pilot area. The 4 boundaries in red are representing the IKONOS image scenes.

Scene ID	Acquisition Date
173244	25/08/2003
173256comp1	09/02/2000
173256comp4	01/07/2002
173256comp5	14/02/2003

4.2.4. **Post tsunami imagery** over the pilot project. The blue area of interest represents a quickbird image

Scene ID	Acquisition Date
5511495080_01	16/01/2005

4.2.5. The total area of the zone of interest is approximately 449.30 Km^2.

4.3. Ground control

4.3.1. To perform a correct ortho-rectification using the RPC function we need to have accurate ground control, a digital elevation model and the raw uncorrected image. The selection of the ground control points to be measured is extremely important for the final geometric result of the rectification. We spent therefore some time in order to find the best possible points to be measured in the field.(for a detailed description of the points see **annex 4**).

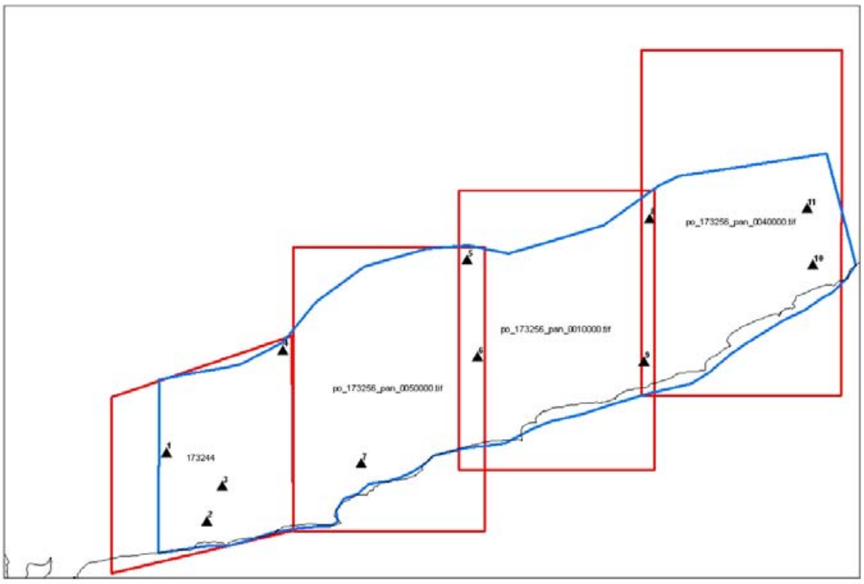
4.3.2. The Team of UDA who will be responsible of the future ortho-rectification of the imagery had trained GPS users in its staff. Furthermore, the motivation of the entire team was very high and so was their learning- ability in the manipulation of DGPS equipment.

GPS team learning the functions of the Trimble GPS controller

4.3.3. Measured ground control over the test area:

- One of the geodetic points part of the network has been used as base-station or reference point. The location of this point is situated at the premises of the UDA local office in Hambantota. The geodetic point is materialized by the geodetic service with a concrete block of approximately 3 meters high. The point itself consists out of a metal pin on top of the block. (see picture below).

- The pilot area is covered with 4 image scenes for what concerns the pre tsunami imagery, and with one image scene for the post tsunami imagery. We have positioned the GCP's (ground control points) in the overlap areas off the adjacent IKONOS image scenes.



- The result after post-processing the GPS measurements is shown in the table below. The coordinates listed are in the projection system UTM (universal transverse mercator) using zone 44 North and with the Ellipsoid WGS84. The absolute precision of these points is cm accurate with respect to the reference geodetic point.

Point Number	x[m]	y[m]	Ellips. Height [m]	Orthom. Height [m]
2	507424.11	676479.69	-94.67	3.16
2A	507269.51	676552.31	-91.58	6.22
1	504881.56	680577.97	-93.55	4.26
3	508191.54	678613.09	-77.94	19.86
4	511731.04	686569.79	-42.76	55.07
7	516323.03	679956.05	-96.10	1.70
6	522681.55	686433.47	void	7.03
5A	522542.64	691867.14	void	44.70
8B	533256.42	694339.91	-83.34	14.49
11	542541.56	694962.34	-88.96	8.89
10	542831.58	691627.52	-94.97	2.88
9	533408.01	686696.93	-93.18	4.63
reference	514137.21	677902.14	-88.00	9.80

4.4. Quality assessment Trimble GeoXT

4.4.1. Measuring Ground Control points for ortho-rectification of VHR satellite imagery should have as a rule of thumb a 3 times better accuracy then the expected RMSE of the rectified image. Because we expect imagery to be below 2 m RMSE (1D) we should use GCP's with a quality of less then 0.66 cm.

4.4.2. The GPS equipment that has been purchased by UDA is one Trimble GeoXT receiver. The results of these measurements are then post-processed using a fixed reference station from another organisation in COLOMBO. In order to estimate the absolute accuracy of the measurements performed with the GeoXT we have measured the same points both with the Trimble 5700 DGPS and the Trimble GeoXT.

4.4.3. Comparison Trimble GeoXT coordinates post-processed from the Hambantota Reference station (max distance within 20 km)

reference coordinates				GeoXT postprocessed via Hambantota station					
PtNr	x[m]	y[m]	MSL [m]	X	Y	MSL (m)	dx	dy	error
6	522681.55	686433.47	7.03	522682.02	686433.75	6.31	-0.47	-0.28	0.55
5A	522542.64	691867.14	44.70	522542.91	691867.60	43.69	-0.27	-0.46	0.53
11	542541.56	694962.34	8.89	542540.90	694962.44	8.29	0.66	-0.10	0.67
10	542831.58	691627.52	2.88	542830.87	691627.40	3.06	0.71	0.12	0.72
9	533408.01	686696.93	4.63	533407.91	686696.79	4.92	0.10	0.14	0.17

GeoXT postprocessed via Colombo station					
X	Y	MSL (m)	dx	dy	error
522682.61	686434.04	11.64	-1.06	-0.57	1.21
522542.96	691867.27	49.24	-0.32	-0.13	0.35
542541.16	694963.00	14.17	0.40	-0.66	0.78
542831.30	691626.91	9.47	0.29	0.61	0.68
533409.02	686697.21	11.18	-1.00	-0.28	1.04

4.4.4. The table shows that the GeoXT files post-processed by a reference station with a maximum baseline of 20 km gives acceptable results for GCP collection.

4.4.5. However, using a reference-station in Colombo (around 170 Km) gives results which will influence negatively the results of the ortho-rectification.

4.4.6. RMSE values for the GeoXT coordinates post-processes from the local Hambantota reference-station are RMSEx = 0.50 m and RMSEy = 0.26m, while the RMSE values for the GeoXT calculated from the reference-station Colombo are RMSEx = 0.70 m and RMSEy = 0.50m.

4.5. Digital elevation model

4.5.1. Although the pilot area is mostly flat, a digital elevation model (DEM) must still be used in order to have no risks in the quality of the ortho-rectification.

4.5.2. The DEM used is the SRTM (The Shuttle Radar Topography Mission) [5] 3-arcsec. Data studies in the JRC[6] have shown that most of the SRTM data has a geometric quality of better than 5m RMSE, suitable for the task.

[5] http://www2.jpl.nasa.gov/srtm

6 Study by Rafal Zielinski "Quality elevation of SRTM basic DEM" Internal JRC document file://S:\FMPArchive\P\3371.doc. For a copy contact peter.spruyt@jrc.it

4.5.3. Using the accurate ground control points measured using DGPS, we can perform a geometric quality control of the digital elevation model. Note that the elevations are orthometric height above the WGS84 ellipsoid.

Point Number	*Orthom . Height [m]*	*SRTM height (m)*	*Dx*	*Dx^2*
2	3.16	4.65	-1.50	2.24
2A	6.22	6.07	0.15	0.02
1	4.26	3.45	0.81	0.65
3	19.86	19.85	0.01	0.00
4	55.07	54.01	1.06	1.11
7	1.70	3.89	-2.19	4.81
6	7.03	3.13	3.90	15.19
5A	44.70	44.19	0.51	0.26
8B	14.49	11.50	2.99	8.93
11	8.89	7.39	1.50	2.25
10	2.88	3.06	-0.18	0.03
9	4.63	3.83	0.80	0.64
			RMSEz	1.74

4.5.4. This resulted in an RMSEz of the Digital elevation Model used for the ortho-rectification of 1.74m, confirming the JRC results assessed elsewhere, and very suitable for performing an accurate ortho-rectification.

4.5.5. The complete DEM derived form the SRTM dataset has been delivered to UDA in order to ortho-rectify the remaining images.

5. Ortho-rectification Techniques

5.1.1. To rectify an image there are different approaches. The choice of the approach depends upon the expertise of the operator/surveyor and on the available software.

- Warp: .Also called polynomial or rubber-sheet transformation. This method makes no account for terrain. This can be used for medium resolution satellite imagery on the condition that the image is taken vertically and that the terrain is flat (or low). Generally speaking this approach is NOT suitable for working on VHR satellite images (such as Quickbird and/or IKONOS).

- Block adjustment: Join images together in overlapping zones. This approach is similar to an aero-triangulation/adjustment. Here we have usually not a full stereo cover, a slight weaker geometry and a more complex modeling (which results in more expensive processing software). This approach is however the only solution for reducing ground control for a large number of images, and is somewhat more complex to apply.

- Stereo approaches : This is technically the most sophisticated solution. This approach also permits the extraction of Digital Elevation Models, but requires the most expensive software to undertake. Also what image acquisition is concerned this approach becomes expensive because overlap of imagery is necessary to perform the above mentioned technique.

- Single scene Ortho-rectification[7] using RPC[8] function (space resection). This is the most appropriate solution for our project because we have to rectify a narrow strip along the coastline, and because this approach, compared to stereo approaches and/or block adjustment, is less complex to handle. Furthermore the software solution is the least expensive. This approach is selected because it is precise enough and easy to implement.

5.1.2. Ortho-rectifying using RPC function. **Inputs**

- RPC (Rational Polynomial Coefficient) file. This file is delivered by the image provider together with the raw images. (Gives information on position of satellite when imagery was taken (exterior orientation)
- Ground control points necessary to refine the RPC. In principle 1 GCP is enough per image scene. However we suggest 4 points. The quality of GCP's should be better than 50 cm RMSE 1-D; the only way to obtain this is using DGPS and/or terrestrial survey methods.
- Digital elevation model to solve displacements because of terrain. Less then 5m RMSE[9].

5.2. Ortho-rectification results – Residuals on control points in Indonesian Pilotproject (Banda Aceh)

5.2.1. No checkpoints have been measured during the visit due to time-restrictions. However, in the future, when all necessary land-surveying material is available in BPN Banda Aceh, this should be a standard procedure for a sample of processed images in order to have a geometric quality control of a randomly selected nr of image scenes. For guidelines in quality control of ortho-rectified imagery we would like to refer to our document: http://agrifish.jrc.it/documents/lpis/2402v2_4.pdf

5.2.2. Nevertheless, a statement of the geometric accuracy of the imagery can be made using the residuals of the GCPs used in the orthorectification process. These residuals are the distances between the input and retransformed coordinates in the rectified image. They are shown for each GCP in the "X Res" and "Y Res" columns.

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7 Orthorecification is the mathematical process of removing the distortion caused by relief and the sensor within an imagescene so that the scale is uniform throughout the output image. In essence, the image can be considered a map.

8 The RPC or Rational Functions Math Model uses the rational polynomial as the geometric model. Users can collect their own GCPs to generate their own rational function or orthorectify an image directly using the rational function contained within a file or separate RPC text file

9 See guidelines for best practice and Quality checking of ortho imagery.http://agrifish.jrc.it/documents/lpis/2402v2_4.pdf

Imagescene 193049 _ p002		
GCP	**Xres(m)**	**Yres(m)**
7	0.02	0.09
2	0.037	0.16
9	-0.06	-0.25
6B	-0.00	-0.00
GCP RMS ERROR	**0.035**	**0.157**

Imagescene 193049 _ p003		
GCP	**Xres(m)**	**Yres(m)**
2	0.51	-0.14
6B	-0.78	0.22
10	1.11	-0.31
11B	-0.84	0.23
GCP RMS ERROR	**0.84**	**0.23**

5.2.3. For image 193049 _ p001, no residuals could be calculated since there was only one GCP. For the other two images, these tables show us an indirect confirmation of the quality of the ortho-rectification, since the residuals are well below 1m in all but one case, indicating that a 1/5000 scale standard is probably met. However, in order to have an objective confirmation of the geometric quality a number of independent checkpoints should be measured.

5.3. Ortho-rectification results- Quality statements SRI LANKA (Hambantota)

QUICKBIRD SCENE

5.3.1. From the 12 GPS points measured 4 are used for ortho-rectification of the Quickbird scene, while the other 8 are used as independent checkpoints. This should be a standard procedure for a sample of processed images in order to have a geometric quality control of a randomly selected number of image scenes. For guidelines in quality control of ortho-rectified imagery we would like to refer to our document: http://agrifish.jrc.it/documents/lpis/2402v2_4.pdf

ptnr	*X_gps[m]*	*Y-gps[m]*	*X_ortho(m)*	*Y_ortho(m)*	*dx*	*dy*	*dx^2*	*dy^2*
2	507424.11	676479.69	507424.24	676479.88	-0.13	-0.19	0.02	0.04
2A	507269.51	676552.31	507270.83	676550.18	-1.32	2.13	1.75	4.54
1	504881.56	680577.97	504880.14	680577.89	1.42	0.08		
3	508191.54	678613.09	508190.79	678613.34	0.75	-0.25	0.56	0.06
4	511731.04	686569.79	511731.00	686568.77	0.04	1.02	0.00	1.04
7	516323.03	679956.05	516324.62	679953.29	-1.59	2.75	2.53	7.57
6	522681.55	686433.47	522683.08	686437.01	-1.53	-3.54	2.34	12.55
5A	522542.64	691867.14	522545.07	691867.09	-2.43	0.05		
8B	533256.42	694339.91	533257.77	694342.15	-1.34	-2.25	1.80	5.04
11	542541.56	694962.34	542540.37	694963.47	1.19	-1.14		
10	542831.58	691627.52	542833.40	691627.87	-1.82	-0.35		
9	533408.01	686696.93	533411.67	686695.22	-3.66	1.71	13.36	2.92
				RMSE			1.67	2.05

5.3.2. We can conclude that for the quickbird scene the ortho-rectification was done successfully. An RMSE(1D) in X of 1.67m and Y of 2.05 m indicates clearly a 1/5000 standard is met.

IKONOS SCENES

5.3.3. For a statement of the geometric accuracy of the 4 image scenes IKONOS we can look at the residuals of the GCP's used in the ortho-rectification process (at least 4 GCP's). These residuals are the distances between the input and retransformed coordinates in the rectified image.

5.3.4. For 3 scenes no residuals could be calculated since there where only 3 GCP's available in the image scene (due to the fact that some initial points have been replaced by others once on the field because of access problems). For the one image, the table below shows us an indirect confirmation of the quality of the ortho-rectification, since the residuals are well below 1m in all but one case, indicating that a 1/5000 scale standard is probably met. However, in order to have an objective confirmation of the geometric quality a number of **independent checkpoints** should be measured as done with the quickbird image above.

Imagescene 173244		
GCP	**Xres(m)**	**Yres(m)**
1	-0.295	1.252
2	0.849	-0.876
3	-0.393	-0.592
4	-0.16	0.216
GCP RMS ERROR	**0.497**	**0.826**

6. Pansharpening Techniques

6.1. general Info on pansharpening

6.1.1. before rectification we can perform a pansharpening in order to have the color-information of the multispectral on the highest resolution imagery.

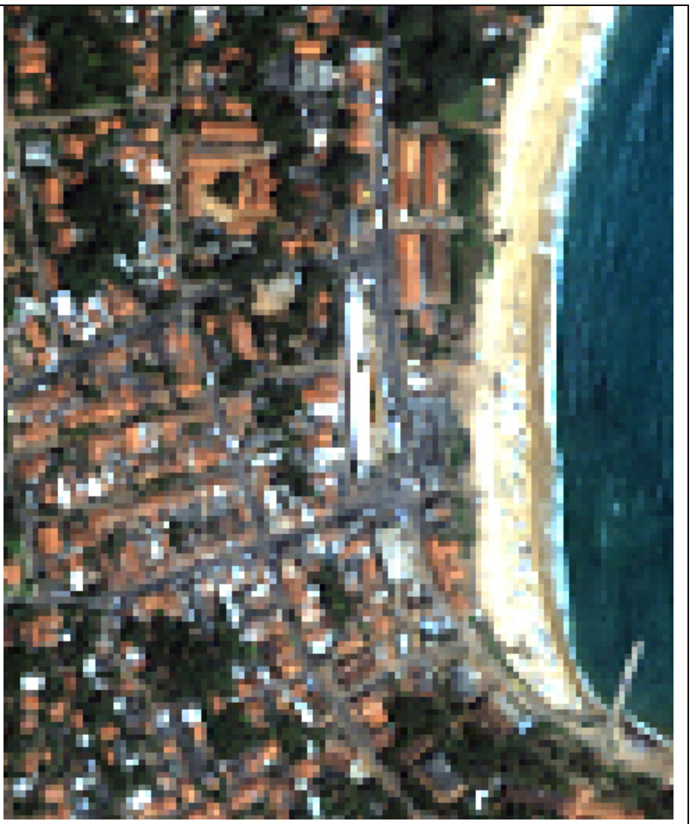
6.1.2. The Pansharpening algorithm "fuses" the high resolution panchromatic and lower resolution multi-spectral imagery to create a high resolution color image. The high-resolution color image preserves the original color fidelity and allows for better visualization and interpretation.

6.1.3. After checking all the possible pansharpening options the best solution for the QuickBird imagery is the Brovey approach (This method uses a ratio algorithm to combine the images) using the Cubic convolution as resampling technique. However, when using IKONOS imagery we have best results using the Principal Component (This method calculates principal components, remaps the high resolution image, then applies an inverse principal components transformation.) with the Cubic convolution as resampling technique.

Banda Aceh (Indonesia)

	
High resolution Panchromatic ortho-rectified image (pre tsunami)	Lower resolution Multispectral ortho-rectified image (pre tsunami)
	
Fusion or pansharpening between High resolution panchromatic image and the lower resolution multispectral image.	Detail of pan sharpened image

Hambantota (Sri Lanka)

	
High resolution Panchromatic ortho-rectified image Post tsunami (hambantota)	Lower resolution Multispectral ortho-rectified image Post tsunami (Hambantota)

Fusion or pansharpening between High resolution panchromatic image and the lower resolution multispectral image.

7. Conclusions and Recommendations for the Indonesian Project

7.1. Conclusions

7.1.1. The delivery of satellite imagery to national authorities in Indonesia has been executed.

- Concerning **pre**-tsunami imagery, the delivery is complete except for:
  - Two areas of Interest covered by IKONOS imagery covering a total of 234km^2 (two scenes); these images are currently on order, and will be delivered as soon as JRC has the received them.
  - An extra area of interest over the Loghna area, covering 56km^2 and 1 image scene; this area will be covered by a QuickBird image that was initially rejected due to a very high cloud cover.
- **Concerning Pos**t-tsunami imagery, the delivery is almost complete, with a small zone of 115km^2 still awaiting acquisition.

7.1.2. We have been able to provide basic technical assistance to the national authorities concerned (BPN Banda Aceh) to help with the **start up** in the use of these data, appropriate image processing and trouble-shooting.

7.1.3. To start up the activity we have been working with a pilot project over Banda Aceh region. This pilot project covers 394km^2 of the total affected area. This approach, working on a small region, was considered the best way to work on transfer of know-how and perform the necessary capacity building of the BPN officials. Furthermore was this the only reasonable approach due to time available during a 2-week mission. During these 2 weeks the technical assistance was not limited to ortho-rectification but covered also different aspects of land-surveying for ground control point collection, pansharpening techniques, general ideas on plotting and all kinds of trouble-shooting related to the above mentioned subjects.

7.1.4. Now that the imagery is delivered the project can start by building on the delivered technical assistance and capacity building initiated during the mission. There is now however a major problem in the BPN Banda Aceh offices concerning the resources for using the imagery.

7.1.5. At present there is a lack of:

- Top end PC's to do image processing,
- image processing software
- DGPS procedures to measure necessary ground control points
- adequate software to perform A0 photo quality plots of imagery with vector overlay.

7.1.6. However, after the visit to BPN Jakarta photogrammetry department, the findings of our earlier mission in February were confirmed, i.e. that all necessary resources required to cover the complete scope of the work are present there. Indeed, for ground control collection there is a set of Dual frequency carrier-phase GPS receivers, and for image processing there are 2 licenses of PCI Geomatica Prime. For plotting activities there are also A0 plotters.

7.2. Recommendations and technical observations

7.2.1. We see two different approaches to continue with the project.

7.2.2. First approach:

- After the capacity building and transfer of know how with staff members of BPN Banda Aceh we were very happy with the technical skills of the officials. The officials of BPN Banda Aceh must therefore be important partners in any further work because of the above mentioned capacity building and because of the present knowledge on the local terrain conditions.
- However, BPN (Jakarta) could start immediately with the collection of the necessary ground control using the GPS equipment from Jakarta. This equipment could for example be loaned for the job to BPN Banda Aceh. The imagery could then be processed in Jakarta, and delivered back to Aceh in both digital and paper formats.
- Alternatively, the DG JRC Ispra could do the selection of the GCP’s to be measured. Image shots and approximation of coordinates would then be delivered to the land-surveyors handling the GPS. JRC would then, after the receipt of the precise coordinates of the GCP’s, perform the necessary ortho-rectification and pansharpening, and would deliver the processed imagery on DVD media. However, this approach would create an extra actor into the processing and may be appropriate only where no operational action can be achieved between the two BPN offices.

7.2.3. Second approach:

- Building a complete **independent** sector in BPN Banda Aceh with necessary resources to perform land-surveying activities using DGPS, ortho-rectification and image processing techniques. This approach is effectively in line with the current Indonesian Authorities proposal for RALAS, currently under funding considerations with the World Bank trust fund. In such a case BPN Banda Aceh has to be provided with a major equipment upgrade:
  - PC’s present in Banda Aceh BPN are not adapted to do any kind of image processing. Furthermore the disk-space is largely insufficient for this imagery. The suggestion is to buy at least 1 powerful computer with large disk space capacity to perform all kind of necessary image-processing.
  - Image processing software for ortho-rectification, pansharpening and other image processing tools for radiometric enhancements.
  - GIS tools for plotting activities, compatible with the RALAS land management system.

- o Dual frequency carrier-phase GPS receiver units for working in Real Time Kinematic using GSM or GPRS techniques We suggest at least one base unit and 2 rover units specifically for ground control requirements.
  - Base station specifications: It is an asset that the base station receiver is a L1+L2, (dual frequency carrier phase receiver), to enable the system for possible higher accuracy measurements (cm). The intention is that data can be collected for post-processing as well as for spreading out differential corrections (rtcm, cmr, etc….) via radio, telephone or the internet.
  - The rover unit specifications: For re-establishing properties using coordinates retrieved from ortho-rectified VHR satellite imagery we think that a sub-meter DGPS receiver is sufficient it should be possible to connect the receivers with an external device (radio, GSP/GPRS phone, internet connection etc) in order to receive the RTCM messages for real time differential GPS measurement. Furthermore should these rover units also be capable of static measurements in post processing mode for performing ground control collection. We expect the receivers to be capable of carrier-phase post-processing in dm accuracy.

8. Conclusions and Recommandations for Sri Lankan Project

8.1. Conclusions

8.1.1. The delivery of satellite imagery to national authorities has been executed for what the archive imagery is concerned and a part of the images in tasking. The rest is still in progress.

- Concerning **pre**-tsunami imagery, the delivery is complete. Total area 13747 km^2.
- **Concerning Pos**t-tsunami imagery, the delivery is still in progress. Foreseen area to be purchased by IKONOS = 7823 km^2, for QuickBird the total area = 6435 km^2. At the moment of the reporting (date 15 September 2005) a total of 9 areas of interest have been delivered, mostly located along the east of the island (thus the most affected area), corresponding to a total of 5448 km^2. (84.66 % completed for what QuickBird is concerned).

8.1.2. We have been able to provide basic technical assistance to the national authorities concerned (UDA) to help with the **start up** in the use of these data, appropriate image processing and trouble-shooting.

8.1.3. To start up the activity we have been working with a pilot project over Hambantota region. This pilot project covers 449 km^2. This approach, working on a small region, was considered the best way to work on transfer of know-how and to perform the necessary capacity building of the UDA officials. Furthermore, this the only reasonable approach due to the time available during a 2-week mission. During these 2 weeks the technical assistance was not limited to ortho-rectification but covered also different aspects of land-surveying for ground control point collection, pansharpening techniques, and all kinds of trouble-shooting related to the above mentioned subjects.

8.1.4. Now that the imagery is delivered, the project can start by building on the delivered technical assistance and capacity building initiated during the mission.

8.2. Recommendations and technical observations

8.2.1. Important to mention that the human resources in UDA are very good. The technical staff working with the image processing software and the GPS receivers are skilled and are perfectly able to insure a good result in ortho-rectification processes. 5 persons have been trained during the 2 weeks mission.

8.2.2. GIS and Image processing licenses

- Software licenses are present in the offices of the UDA. However these licenses are restricted for one year and have been donated after the tsunami disaster. This is the case for licenses of ERDAS IMAGINE 8.7 which is used for image processing and for ARCGIS 9 licenses used for GIS tasks.
- UDA will face problems once these licenses expire. So, a solution should be urgently sought to tackle this forthcoming problem. (Estimated cost would be around 15.000 euro approximately).

8.2.3. GPS receivers

- GPS receivers are important tools in the process of ortho rectifications. It ensures accurate measurements of ground control points. The GPS receivers, now available at UDA offices are insufficient what geometric quality is concerned. The calculations and comparison we have performed and which are described in paragraph 4.3.3. are supporting the statement that an GeoXT, when using reference-station for post-processing at a distance more then 50 Km, is insufficient. See also RMSE calculations in paragraph 4.3.6
- **Solution is to purchase a high end DGPS set using the carrier phase signals**.(estimated cost is greater than 10.000 euro)

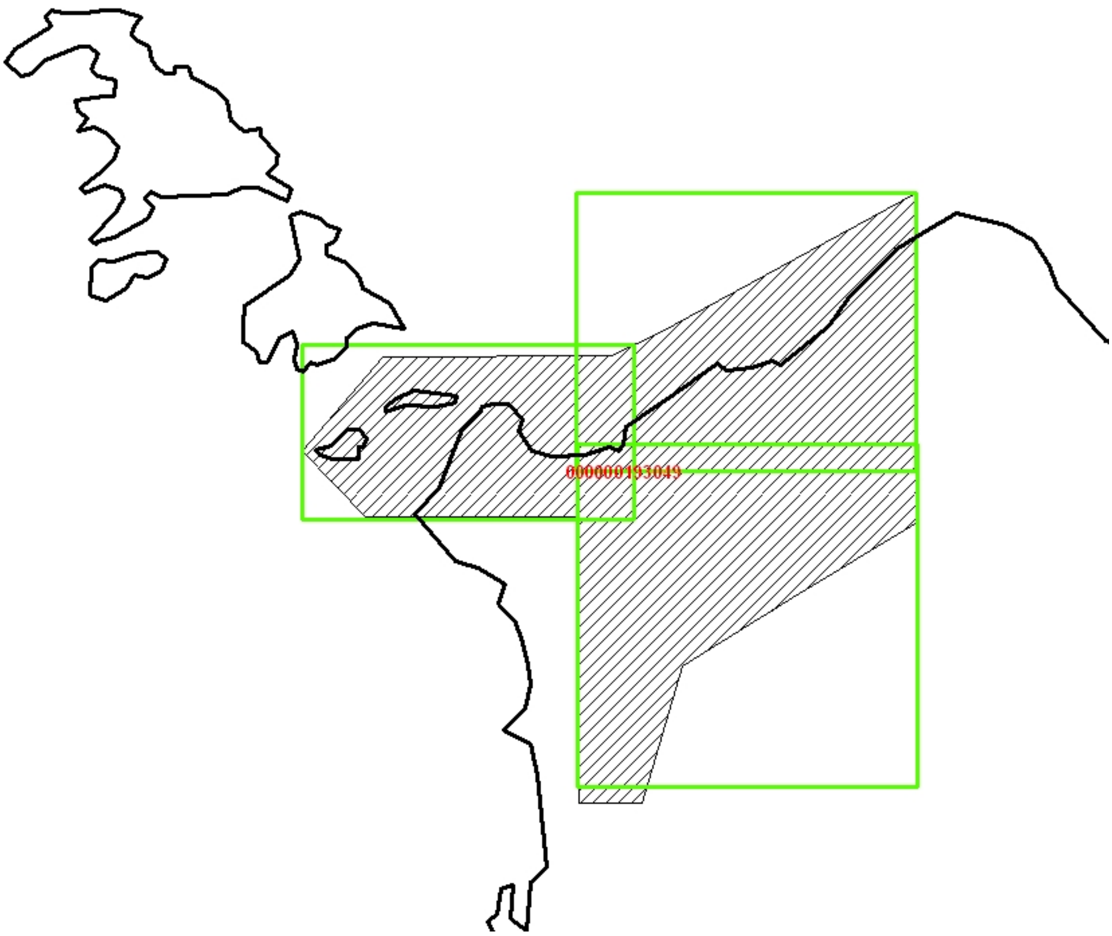
9. Annex 1 : image deliverables Indonesia

9.1. Pre tsunami

Order ID 193049

3 frames with catalogue id

- ***1010010002901203 (overlapping partly with 21776)***
- ***10100100030AC803***
- ***10100100030AC804***

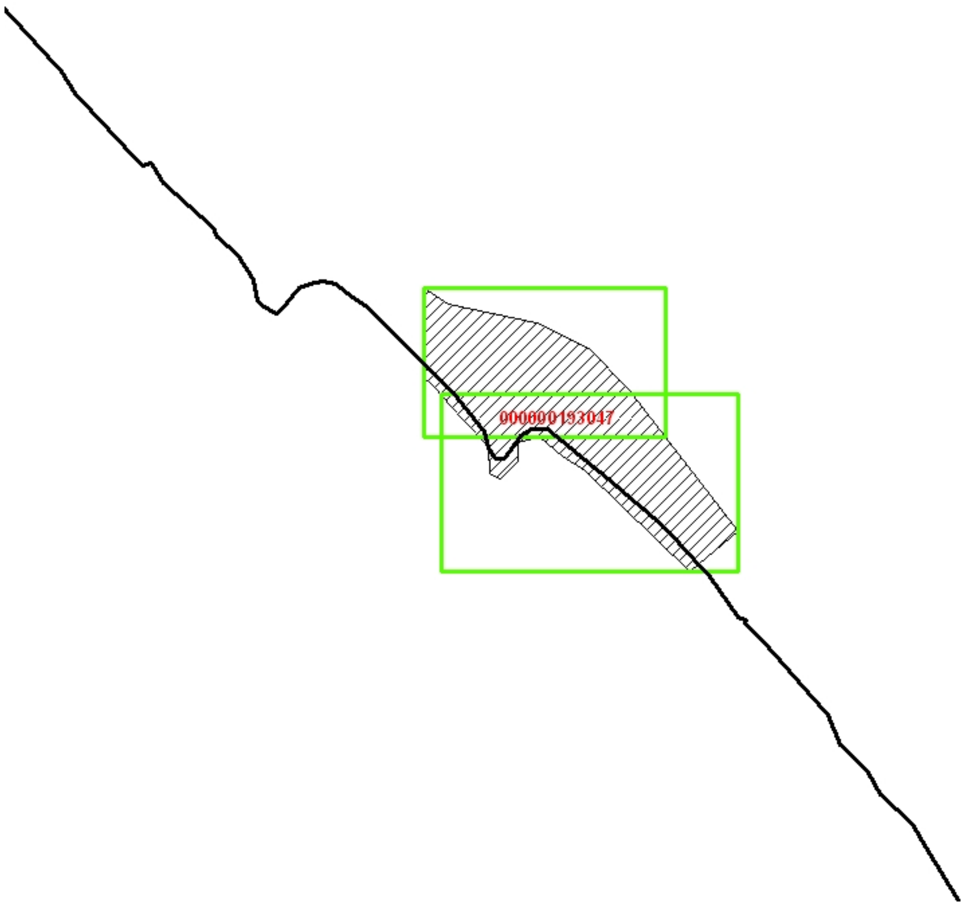


ORDER ID 193047

2 frames with catalogue ID

1010010002F12B09

1010010002F12B0A



ORDER ID 217784 (overlapping order with 193049)

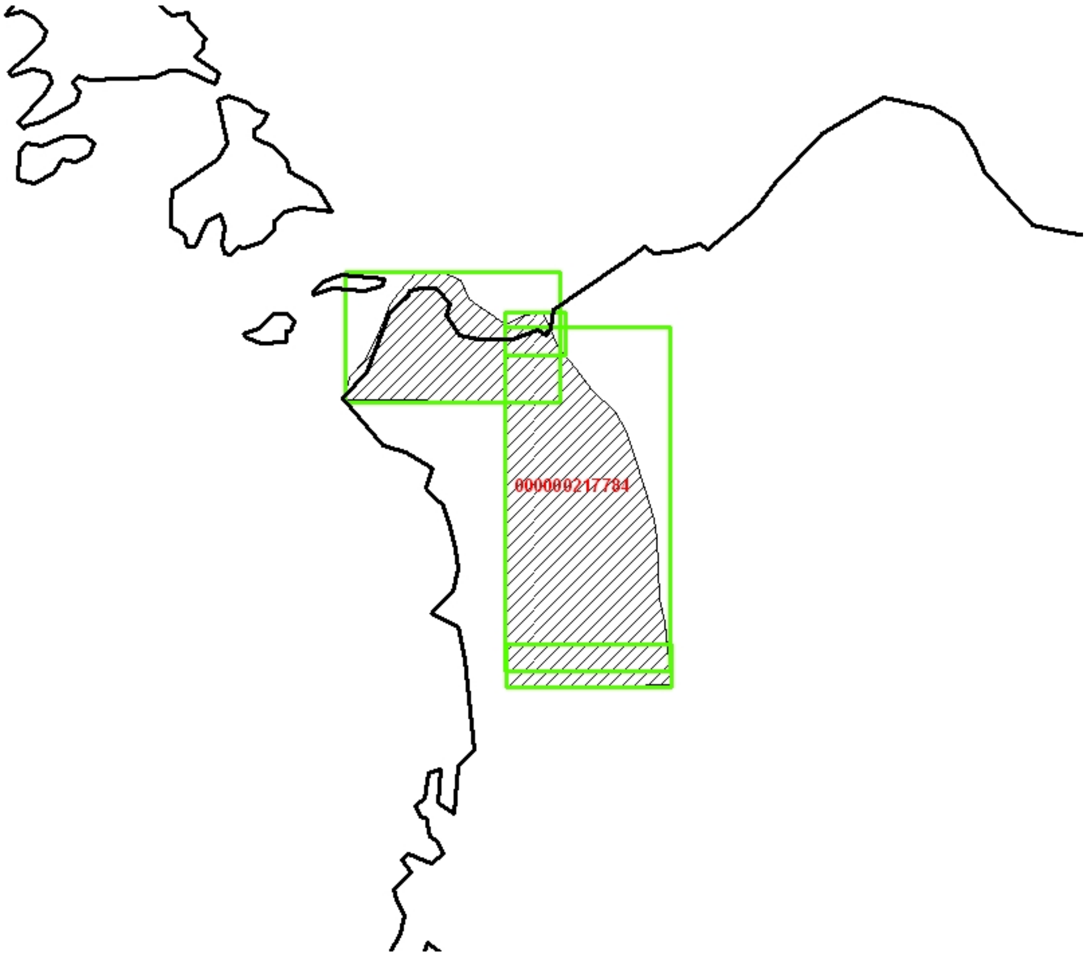
4 frames with catalogue ID

1010010002901203

10100100030AC803

10100100030AC804

10100100030AC805



ORDER ID 217782 (overlapping order with 193047)

2 frames with catalogue ID

1010010002F12B09

1010010002F12B0A

ORDER ID 217781

2 frames with catalogue ID

10100100013B2009

10100100013B200A

ORDER ID 217780

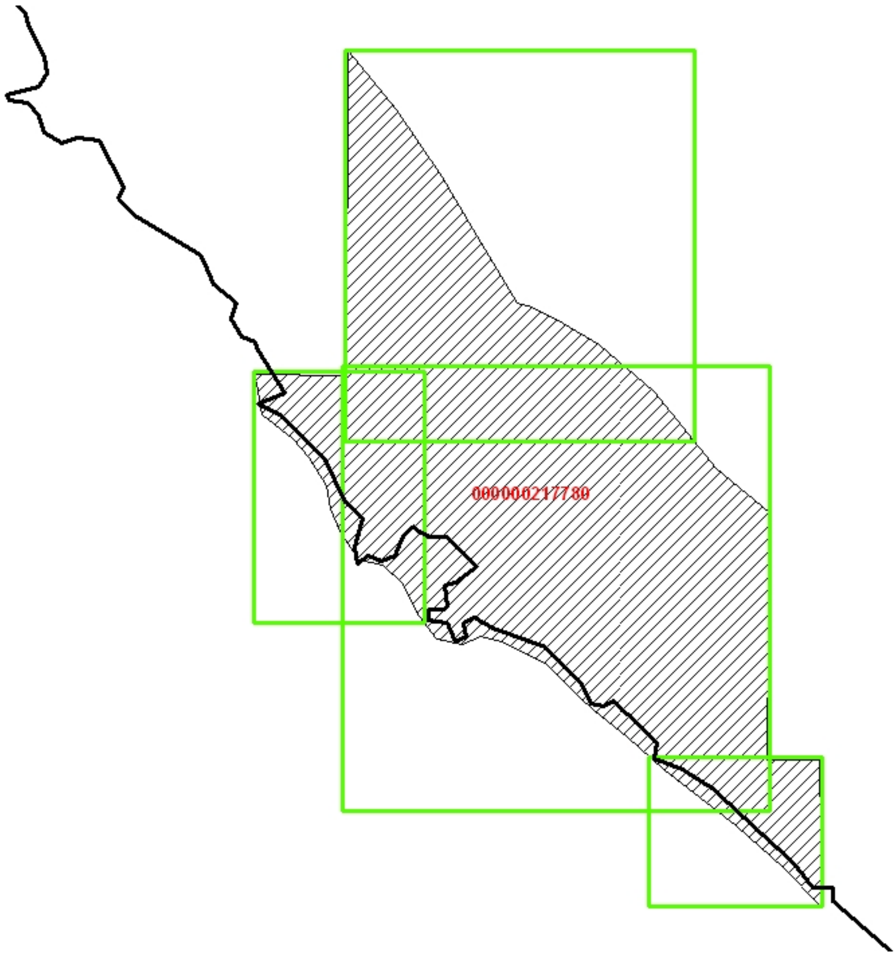
4 frames with catalogue ID

1010010001736202

1010010001894906

1010010001894907

1010010002DD9209

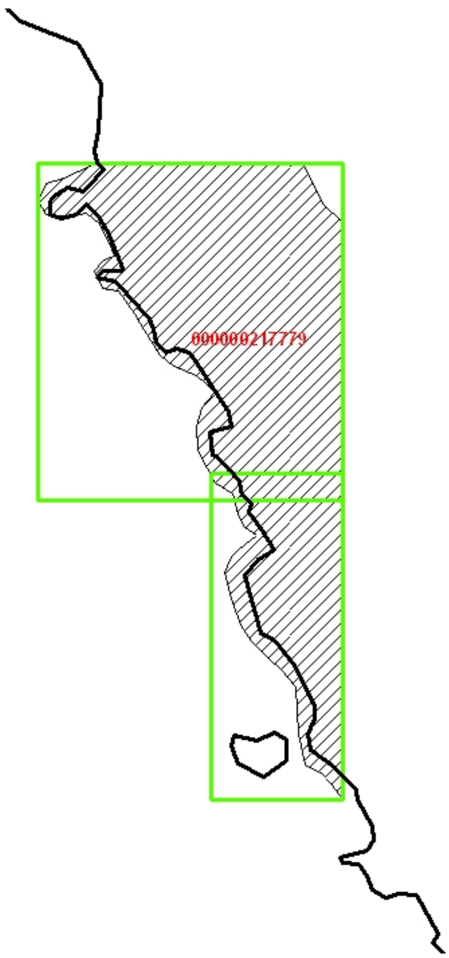


ORDER ID 217779

2 frames with catalogue ID

10100100030AC807

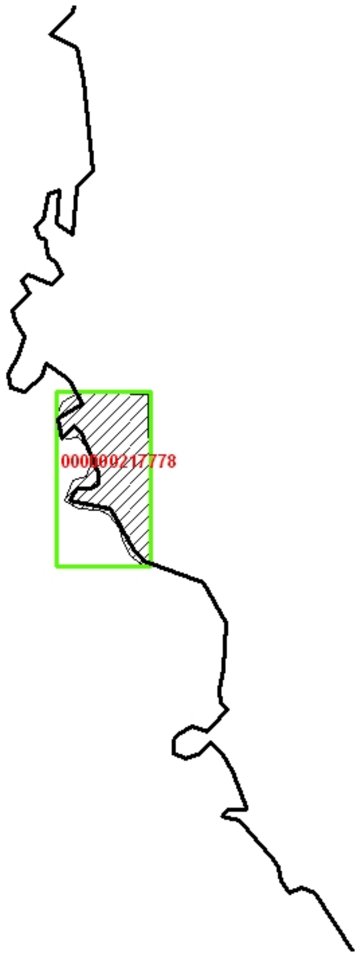
10100100030AC808



ORDER ID 217778

1 frame with catalogue ID

1010010002DA4C06

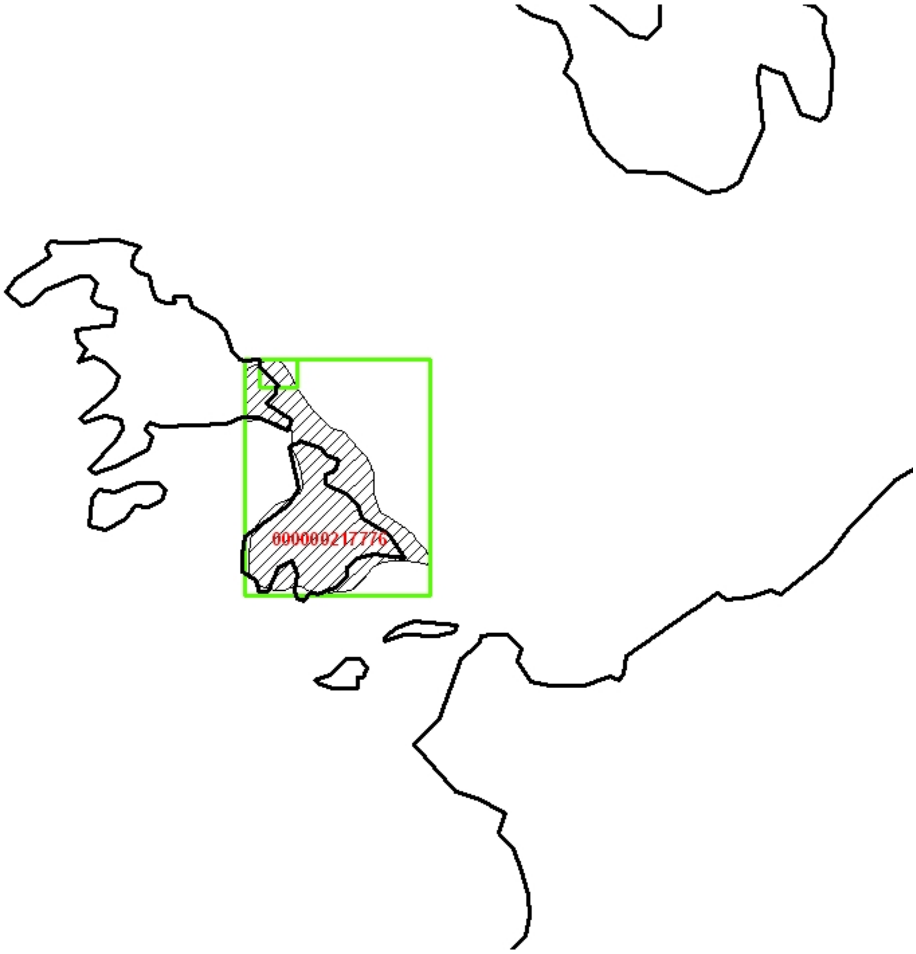


ORDER ID 217776

2 frame with catalogue ID

1010010002901203

1010010002DA4C02

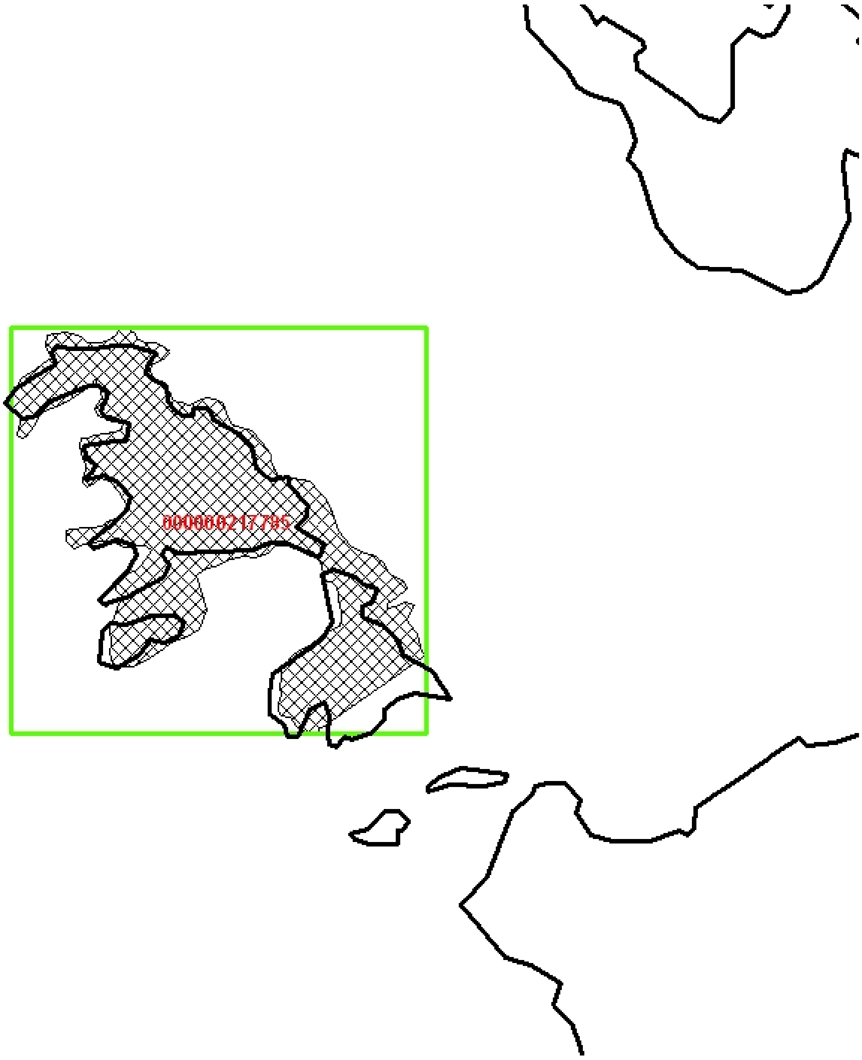


9.2. Post tsunami imagery

Order ID 217785

1 scene with catalogue ID

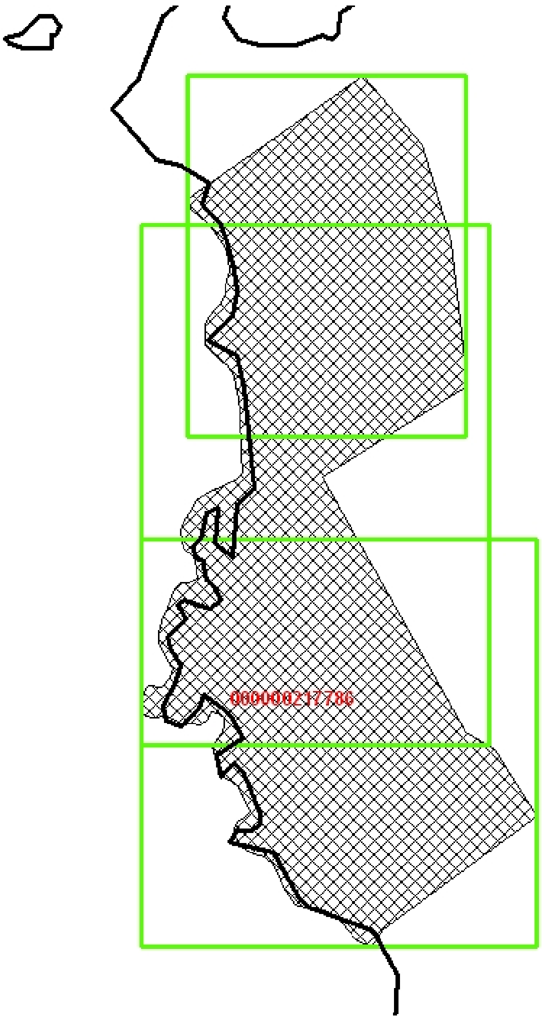
10100100037B2B00



Order ID 217786

3 scenes with catalogue ID

- 101001000387D801
- 101001000387D802
- 101001000387D803



Order ID 217787

13 scenes with catalogue ID

101001000387D805

101001000387D804

10100100037F3209

10100100037F3208

10100100037F3207

10100100037F3206

10100100037F3205

10100100037F3204

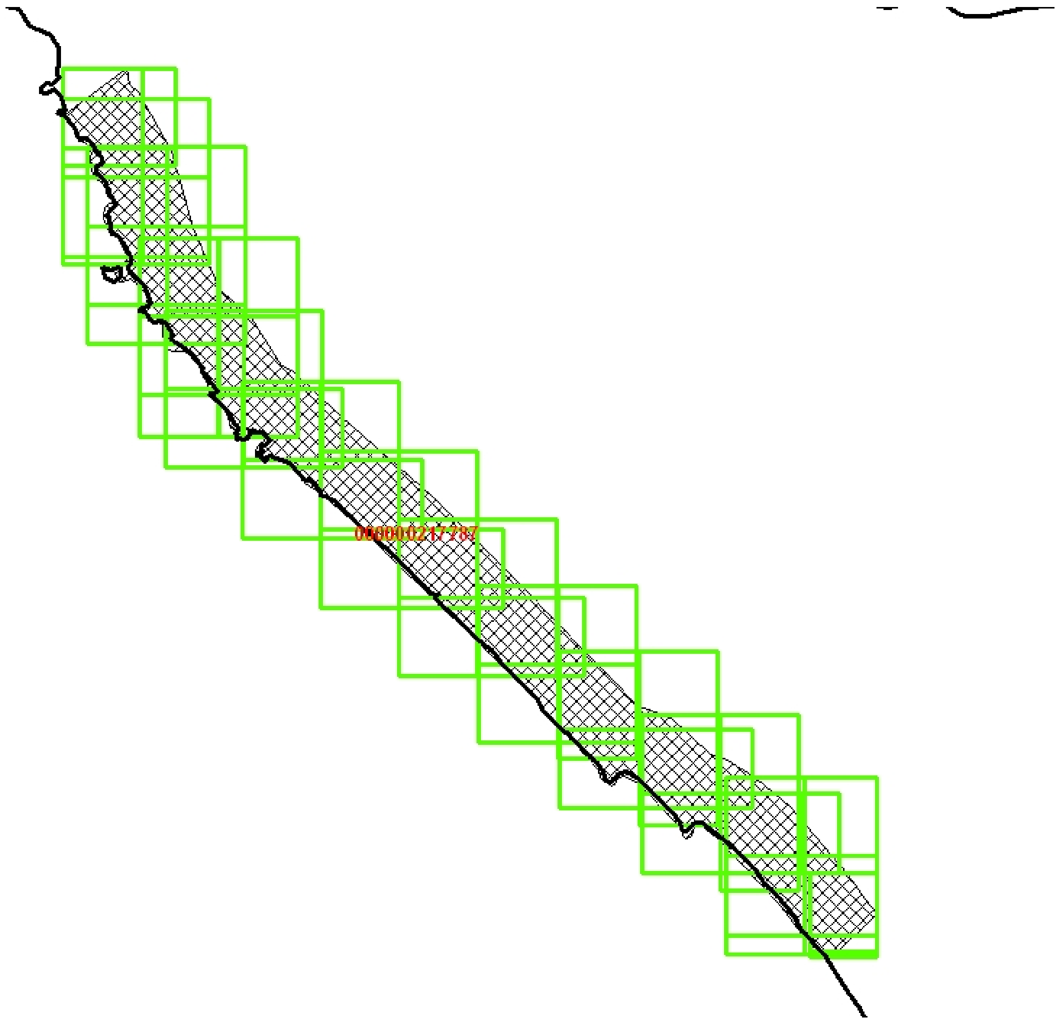
10100100037F3203

10100100037F3202

10100100037F3201

10100100037C9E05

10100100037C9E04

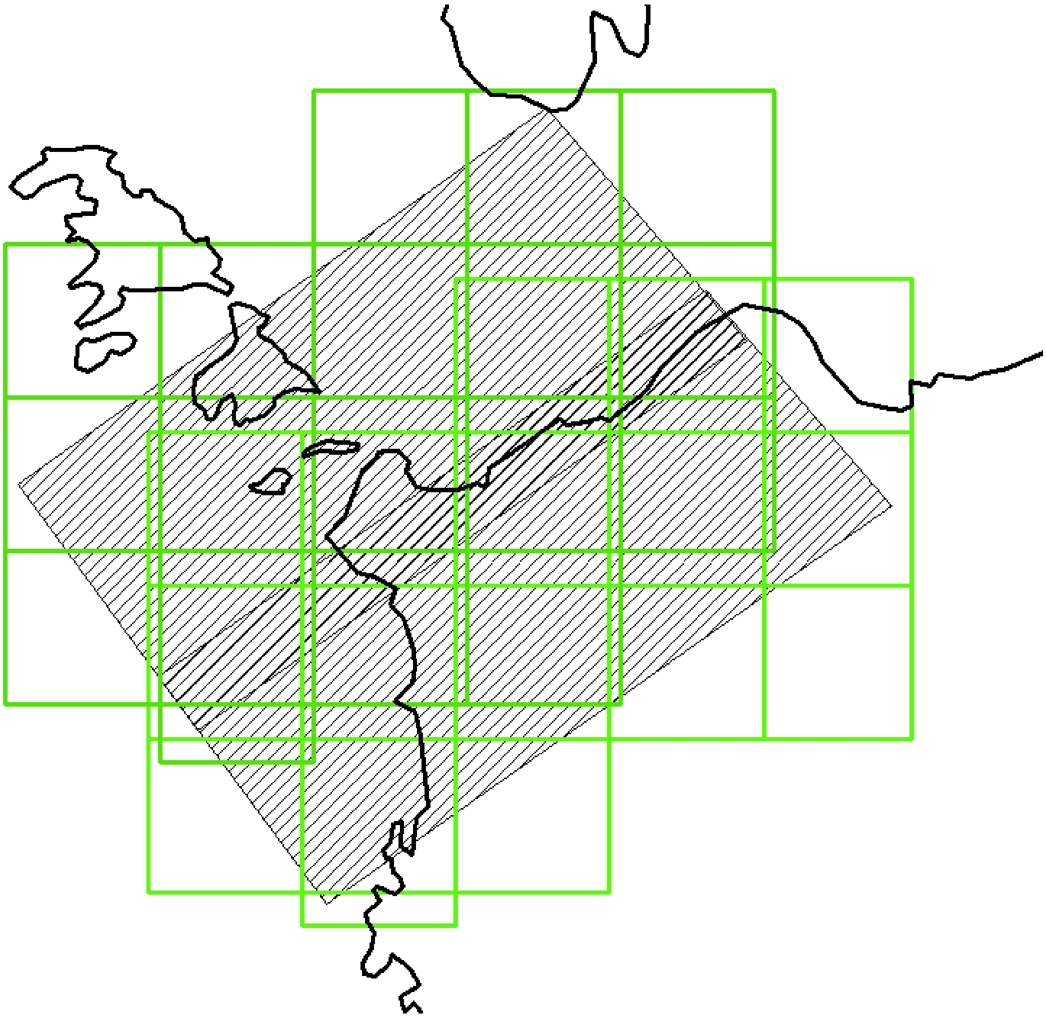


5511374010 and 5511374020 (via ftp)

2 scenes with catalog id

10100100037B2B00

10100100037B2B00

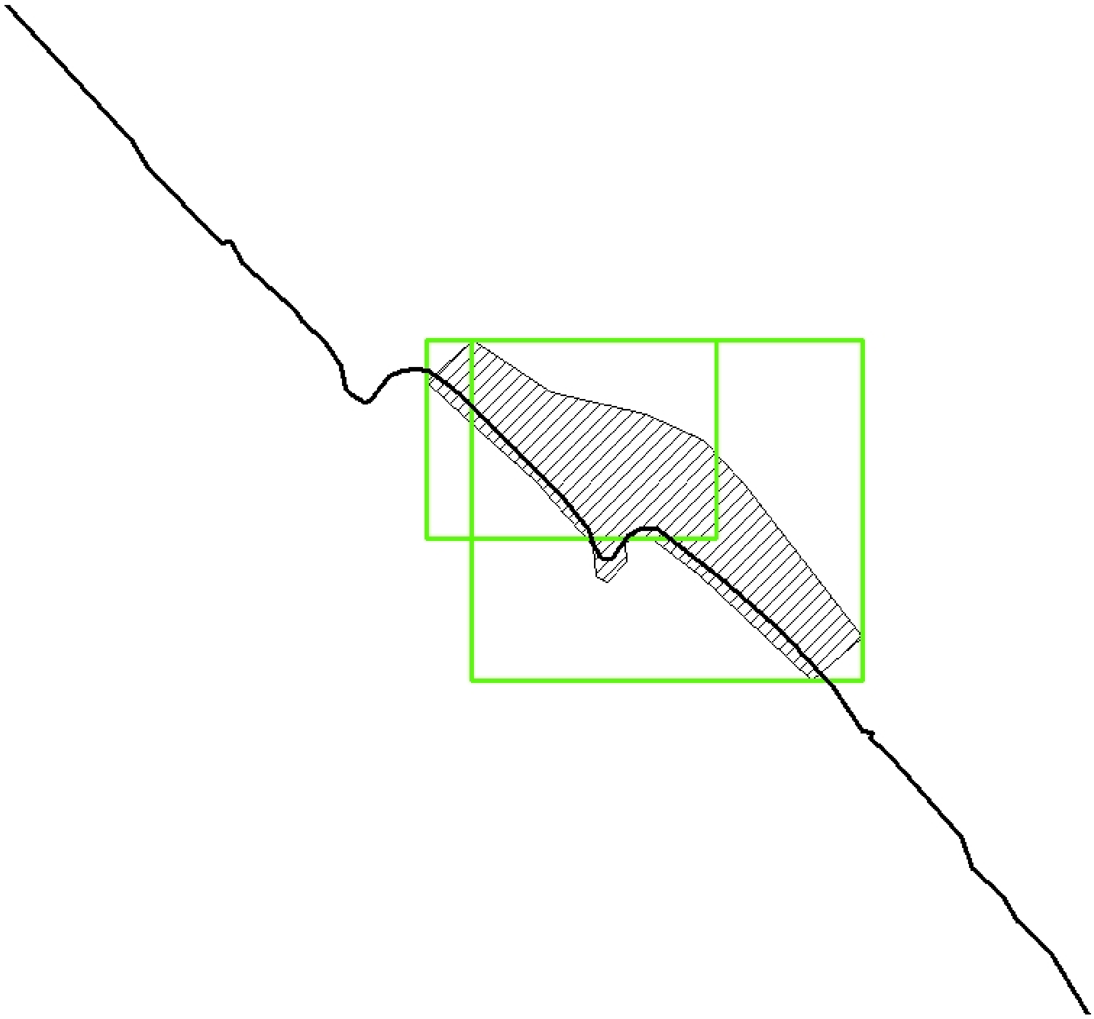


Order ID 193054 (double delivery)

2 scenes with catalog ID

10100100037F3206

10100100037F3207



10. Annex 2 : GCP Banda Aceh – detailed description

10.1. General information on measured ground control points.

10.1.1. The coordinates of the GCP's listed above each GCP are in Lat/long wgs84 Ellipsoid and in UTM zone 46 North with wgs84 ellipsoid.

10.1.2. Quality of the geodetic network. We have measured 2 points of the network. Point S01.001 and point S01.015. PointNr s01.015 (in our project point R) has been used as Base-station position because this point was located on the premises of BPN Banda Aceh offices and could be left alone during the whole day without surveillance. The network has been re-measured by the topographic service of BPN Jakarta after Tsunami.

10.1.3. Measuring point s01.001 using s01.015 as a base we had the following discrepancies: Where S001 is the point measured from the reference S015, and where S001ref is the coordinate as it is in the geodetic network.

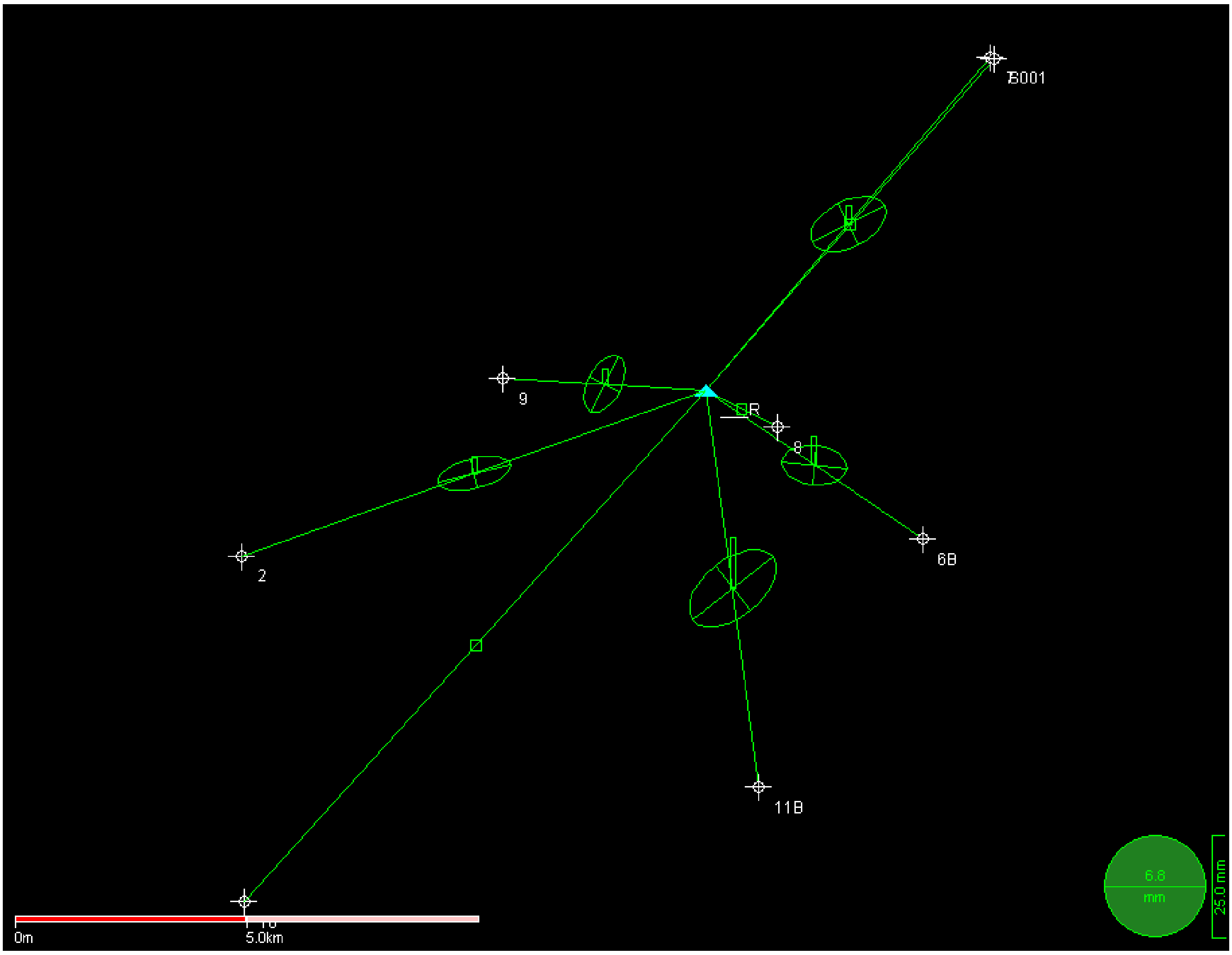
Point Number	*X[m]*	*Y[m]*	*Height [m]*	*dX(m)*	*dY (m)*	*dZ(m)*
S001	767121.10	623960.59	8.29	**0.36**	**0.34**	**0.25**
s001ref	767120.74	623960.25	8.04			

- Coordinates in UTM zone 46 ellipsoid wgs84

10.1.4. We can conclude that the quality of the network, considering regular earthquakes in the region, is acceptable.

10.2. Distances and directions from base towards GCP's

Reference	*Rover*	*True Distance [m]*
___R	S001	9438.35
___R	7	9403.18
___R	10	14823.30
___R	2	10622.98
___R	9	4404.78
___R	8	1729.66
___R	6B	5655.82
___R	11B	8607.66


9
R
8
6B
2
11B
0m
5.0km
6.8
mm
25.0 mm

Reference point position (base point)

Point Nr R (S015)

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
___R	N 5°34'32.81831"	E 95°21'19.12290"	-32.907

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
___R	760928.035	616832.351	2.713

UTM zone 46 North Ellipsoid wgs84

Description

Point located on the parking lot of Banda Aceh BPN offices. Blue concrete block with precise coordinate position embedded in the block. Part of the geodetic network (re-measured after tsunami.

Image

Point S01.001

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
S001	N 5°38'23.94333"	E 95°24'41.20607"	-26.981

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
S001	767121.096	623960.589	8.289

UTM zone 46 North Ellipsoid wgs84

Description

Located around 12 km from BPN offices. Go direction North along the coastline. The point S001 is part of the geodetic network and is embedded in a concrete block painted blue. The point is in the perimeter of a school.

Images

Point Nr 7

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
7	N 5°38'24.61972"	E 95°24'38.68773"	-29.607

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
7	767043.475	623981.056	5.668

UTM zone 46 North Ellipsoid wgs84

Description

This point is a concrete plate inside the perimeter of a private property. This concrete plate is visible on the VHR satellite imagery (post and Pre). Middle of the plate to be taken as point to measure. It is opposite the entrance of the school where point S001 is located.

Images

Point Nr 8

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
8	N 5°34'06.51355"	E 95°22'08.81356"	-31.464

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
8	762461.272	616030.095	4.035

UTM zone 46 North Ellipsoid wgs84

Description

Located inside the perimeter of the university campus. The point-location is the corner of a fence.

Images

PointNr 6B

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
6B	N 5°32'47.49184"	E 95°23'49.85103"	-30.327

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
6B	765582.175	613614.143	4.938

UTM zone 46 North Ellipsoid wgs84

Description

The point taken as a GCP is the crossing between 2 raised rice field' perimeters.

Images

Pointnr 11B

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
11B	N 5°29'54.93048"	E 95°21'55.10943"	-27.795

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
11B	762070.107	608296.87	7.731

UTM zone 46 North Ellipsoid wgs84

Description

The point taken as a GCP is the crossing between 2 raised rice field’ perimeters.

Images

Point Nr 10

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
10	N 5°28'36.16737"	E 95°15'54.70442"	-34.175

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
10	750981.212	605833.536	2.327

UTM zone 46 North Ellipsoid wgs84

Description

Crossing of 2 raised rice field perimeters

Images

Pointnr 2

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
2	N 5°32'38.02343"	E 95°15'53.53864"	-33.049

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
2	750917.088	613265.481	3.42

UTM zone 46 North Ellipsoid wgs84

Description

Crossing between the edge of the road and the middle of the river floating under it.

Images

Pointnr 9

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
9	N 5°34'41.81219"	E 95°18'56.28323"	-33.803

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
9	756528.959	617091.309	2.174

UTM zone 46 North Ellipsoid wgs84

Description

Edge of basin.

Images

(end document)

11. Annex 3 – Pre and Post tsunami imagery – deliverables (on date 2 september 2005)

11.1. Quickbird images PRE

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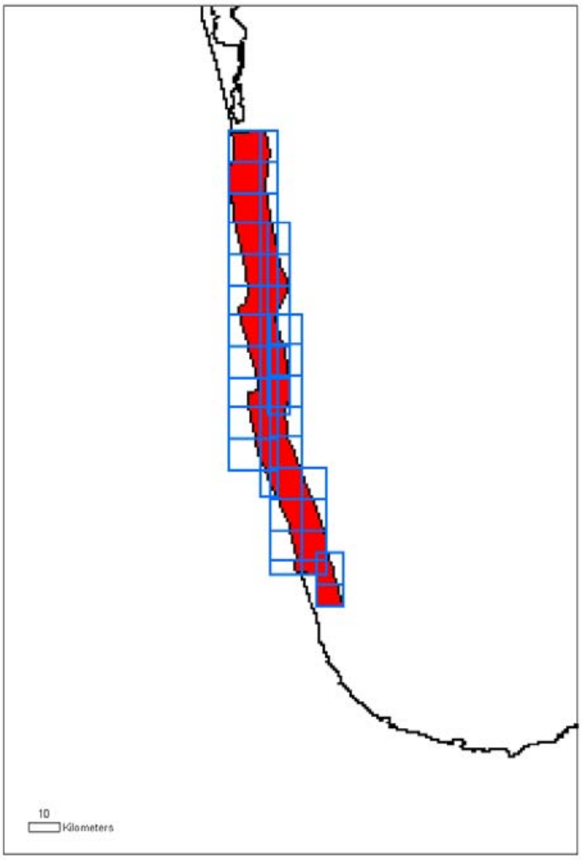	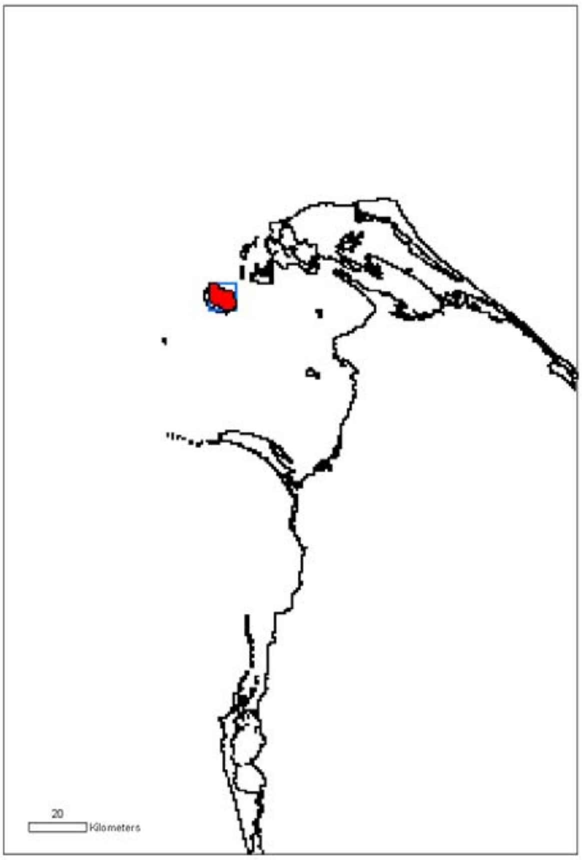

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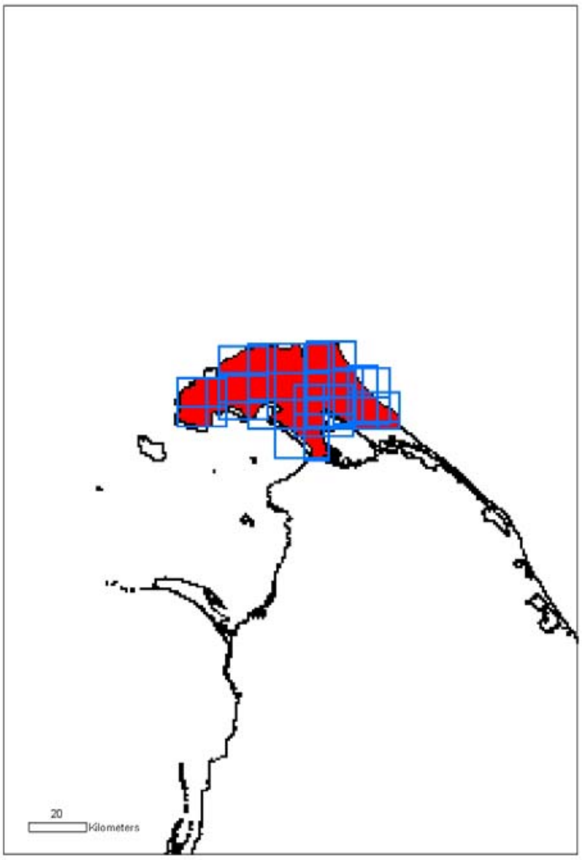	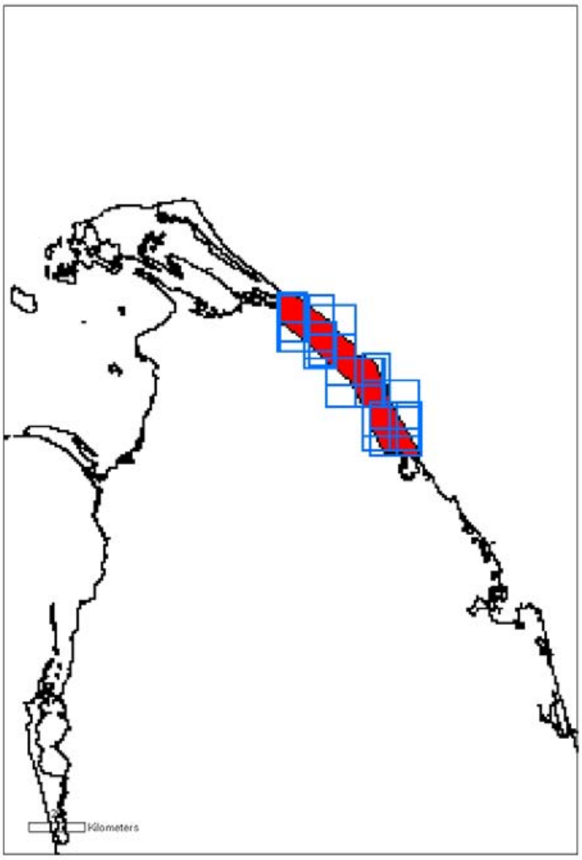

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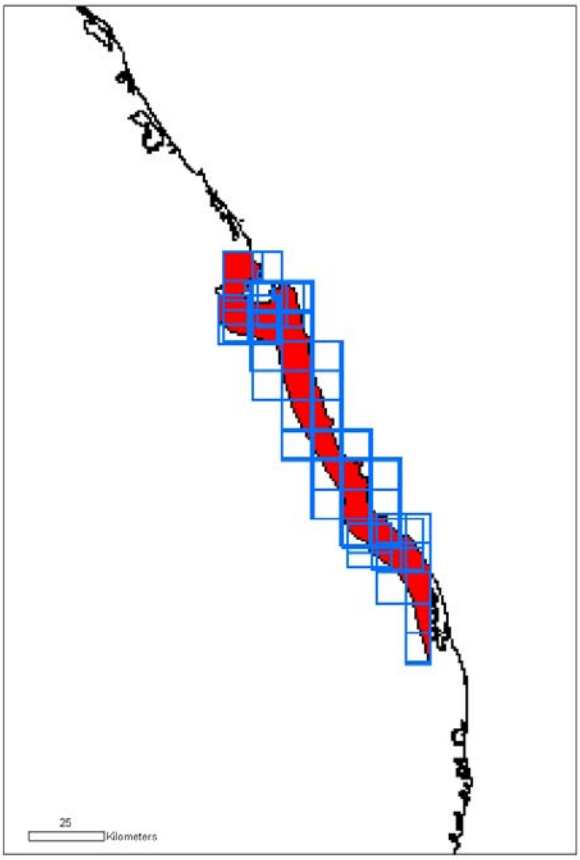	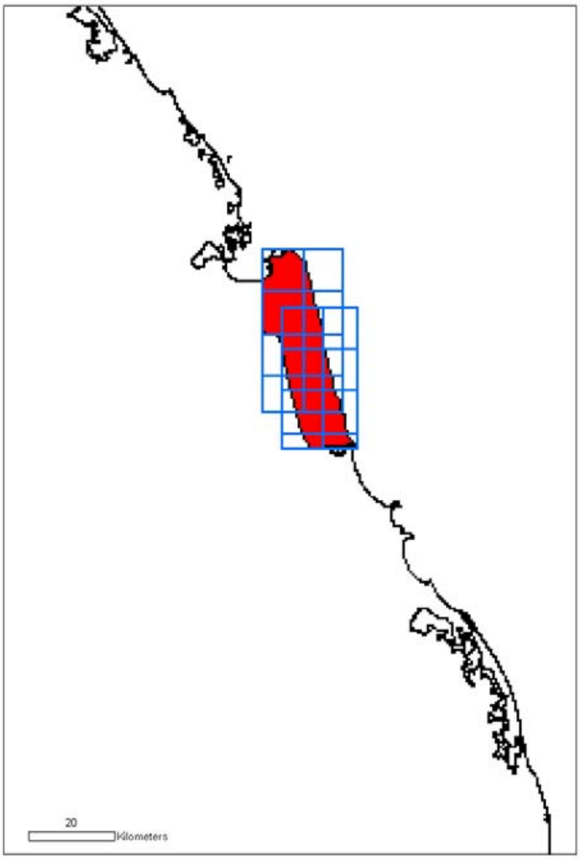

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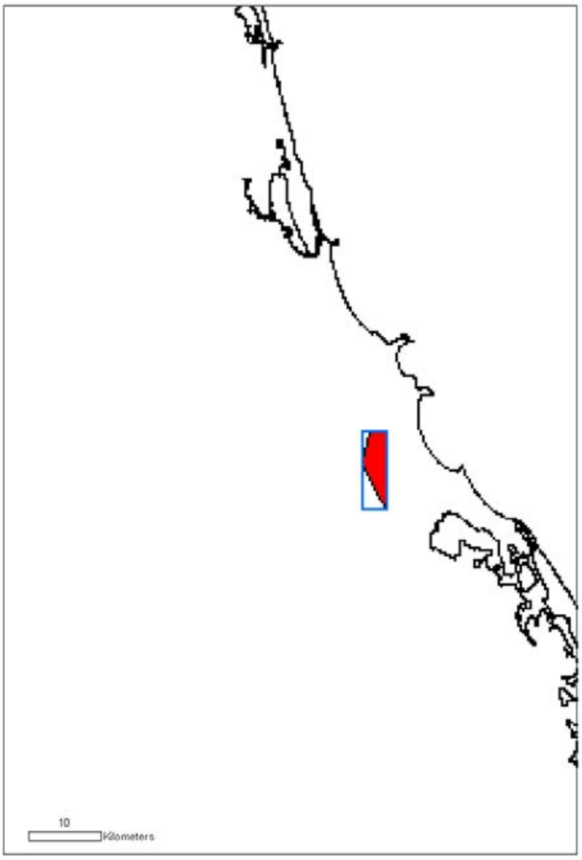	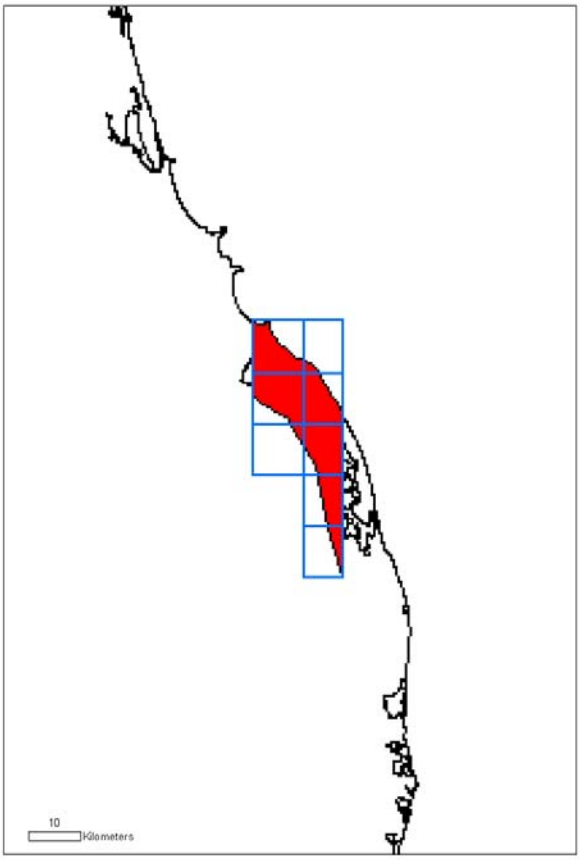

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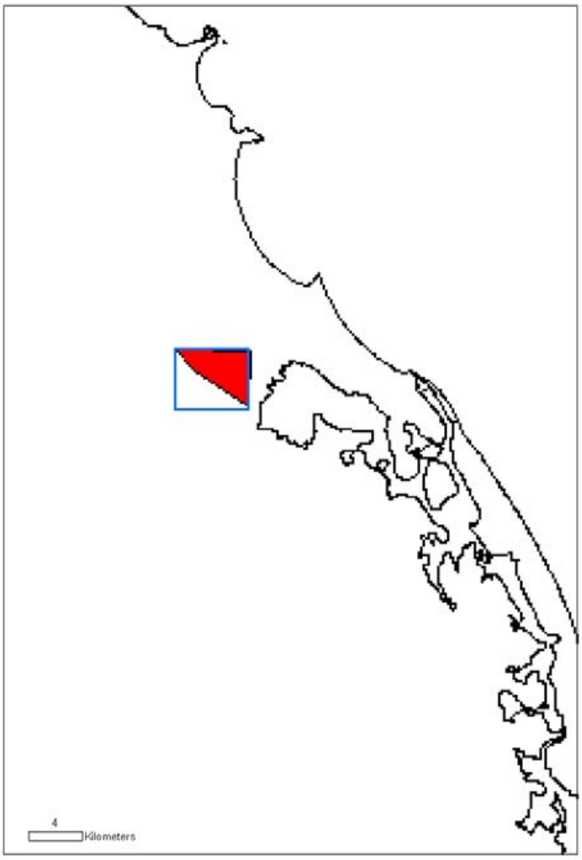	

11.2. Quickbird images POST

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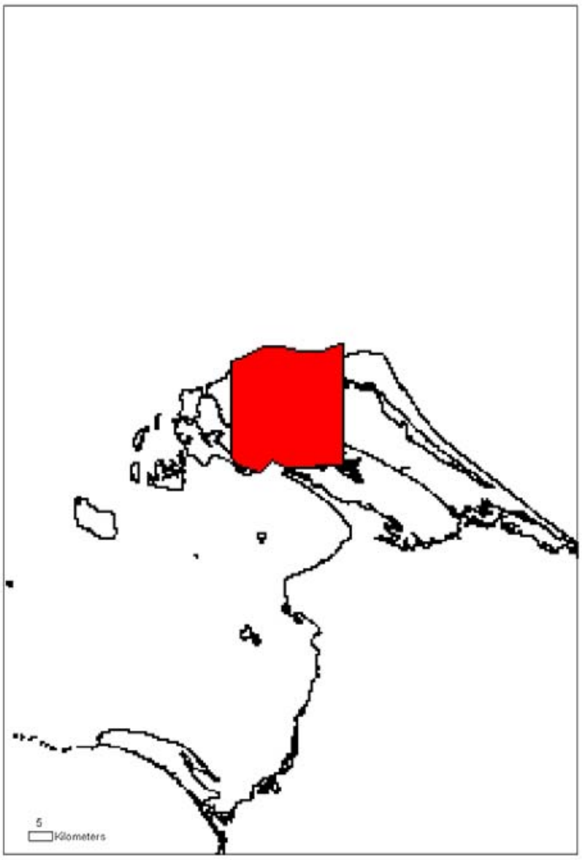	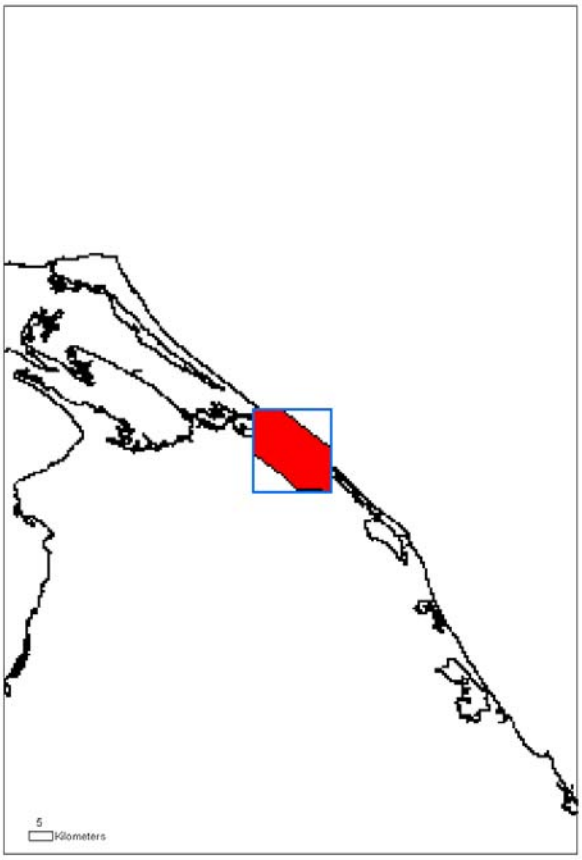

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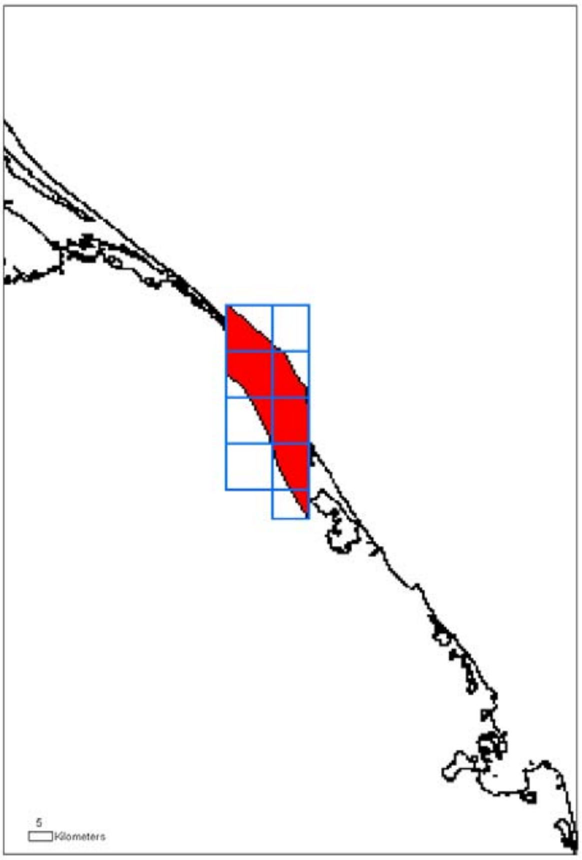	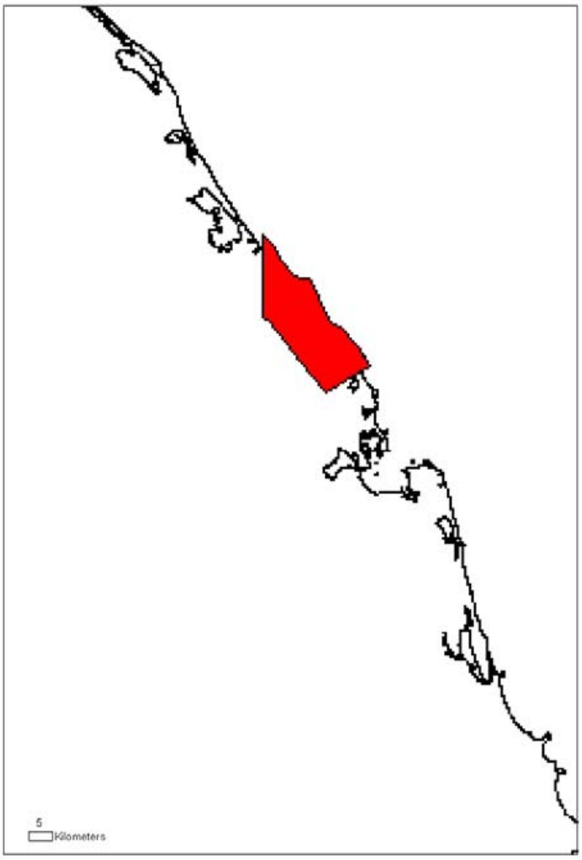

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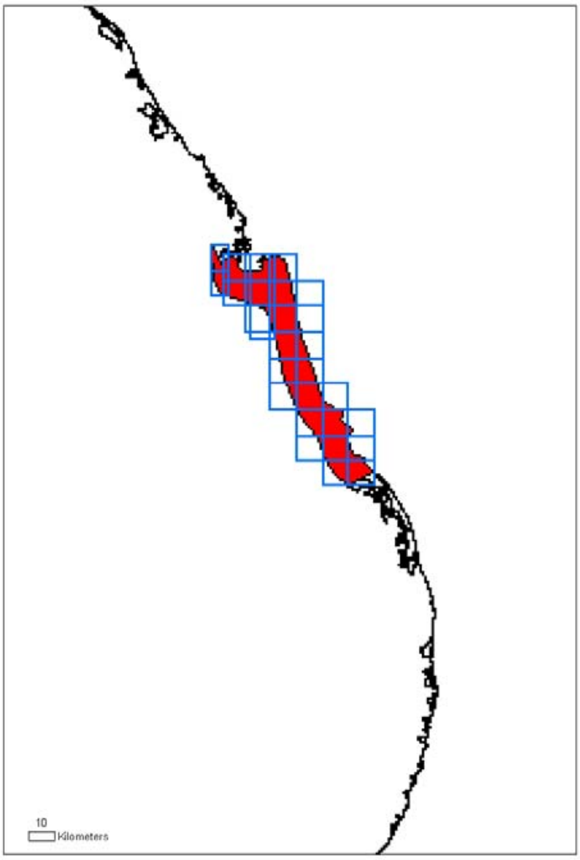
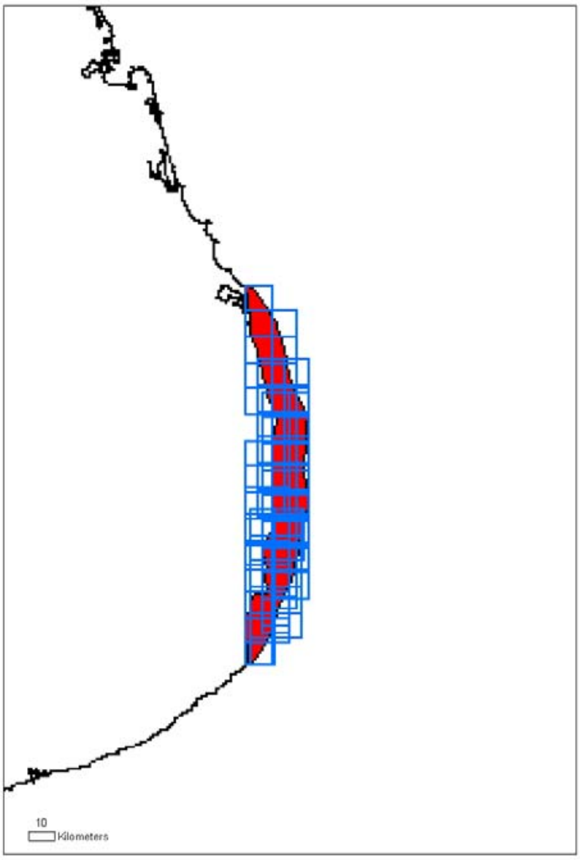
<tr><td>
</td><td>
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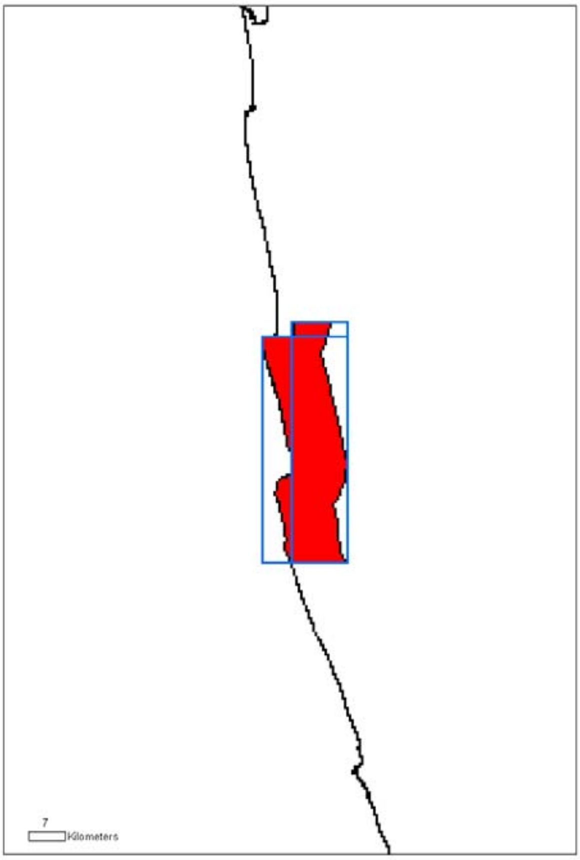	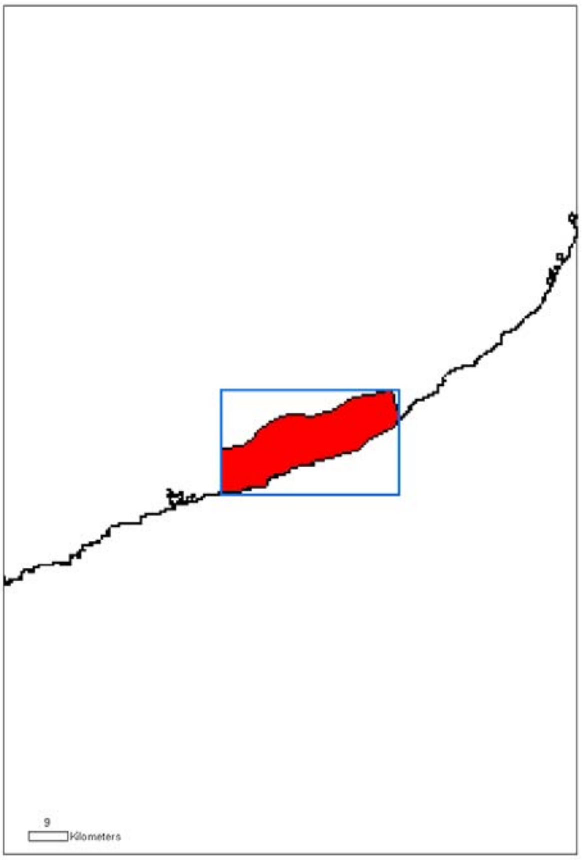

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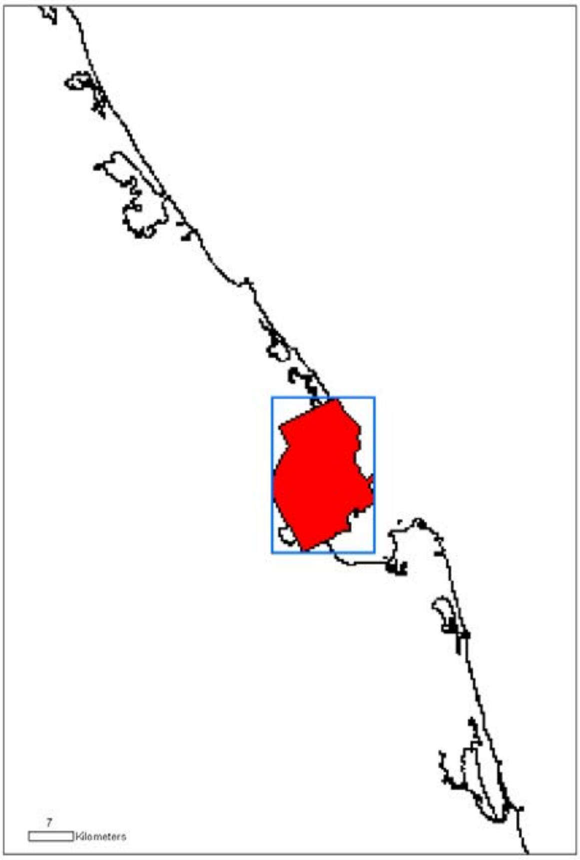	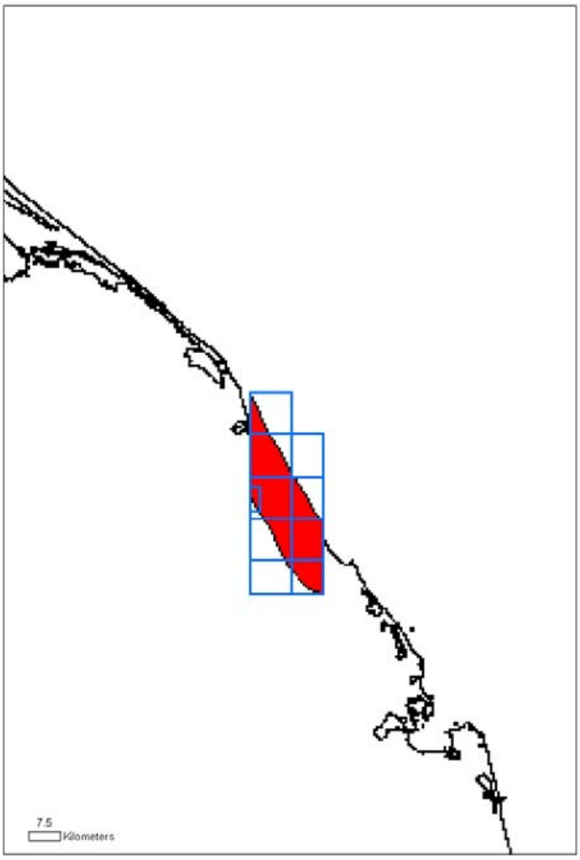

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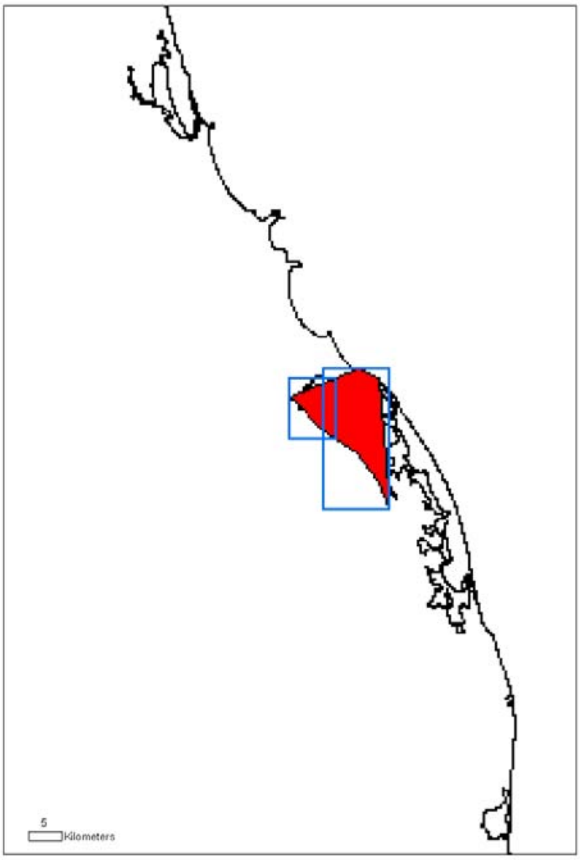
	

12. Annex 4: GCP collection Sri Lanka – detailed description

12.1. General information on measured ground control points.

12.1.1. The coordinates of the GCP's listed above each GCP are in Lat/long wgs84 Ellipsoid and in UTM zone 44 North with wgs84 ellipsoid.

Reference point position (base point)

Point Nr Ref

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
ref	N 6°07'58.59625"	E 81°07'39.98593"	-87.440

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
ref	514137.2	677902.1	9.8

UTM zone 44 North Ellipsoid wgs84

Description

Point used as base-point and which is part of the trigonometric network Sri Lanka. The point is on top of a concrete tower in the backyard of the local land-surveying department in Hambantota. The point itself is imbedded on top of the concrete tower.

Image

Point 2

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
2	N 6°07'12.31163"	E 81°04'01.55448"	-94.068

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
2	507424.1	676479.7	3.16

UTM zone 44 North Ellipsoid wgs84

Description

Approximately 7 km from the basestation, west direction on the main road. Edge of bridge.

Images

Point 2A

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
2A	N 6°07'14.67724"	E 81°03'56.52463"	-91.002

Lat/long Ellipsoid wgs84

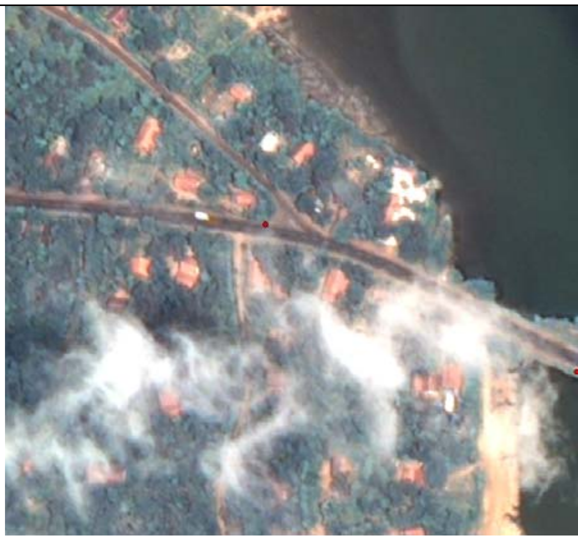
Point Number	X[m]	Y[m]	Orthom. Height [m]
2A	507269.5	676552.3	6.22

UTM zone 44 North Ellipsoid wgs84

Description

Inner intersection between 2 roads. Approximately 7 km west of base station.

Images



Point 1

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
1	N 6°09'25.78716"	E 81°02'38.83983"	-92.696

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
1	504881.6	680578	4.26

UTM zone 44 North Ellipsoid wgs84

Description

Edge of agricultural field. Approximately 9.5 km north-west from base station.

Images

Point 3

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
	N 6°08'21.78588"	E 81°04'26.53353"	-77.249

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
3	508191.5	678613.1	19.86

UTM zone 44 North Ellipsoid wgs84

Description

Intersection between 2 roads. Middle of road at the edge of the other road. Approximately 6 km from basestation.

Images

Point 4

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
4	N 6°12'40.88828"	E 81°06'21.75200"	-41.649

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
4	511731.04	686569.79	55.07

UTM zone 44 North Ellipsoid wgs84

Description

Middle of a rock about 9 km north of base-station.

Images

Point 5

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
5A	522542.64	691867.14	44.70

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
5A	N 6°15'33.30019"	E 81°12'13.64899"	-51.941

UTM zone 44 North Ellipsoid wgs84

Description

Inner intersection 2 roads. Approx 16.3 km from base-station.

Images

Point 6

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
6	N 6°12'36.34411"	E 81°12'18.10106"	-89.887

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
6	522681.55	686433.47	7.03

UTM zone 44 North Ellipsoid wgs84

Description

Crossing of bridge. At approximately 12 km from base station

Images

Point 7

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
7	679956.050	516323.030	-95.458

Lat/long Ellipsoid wgs84

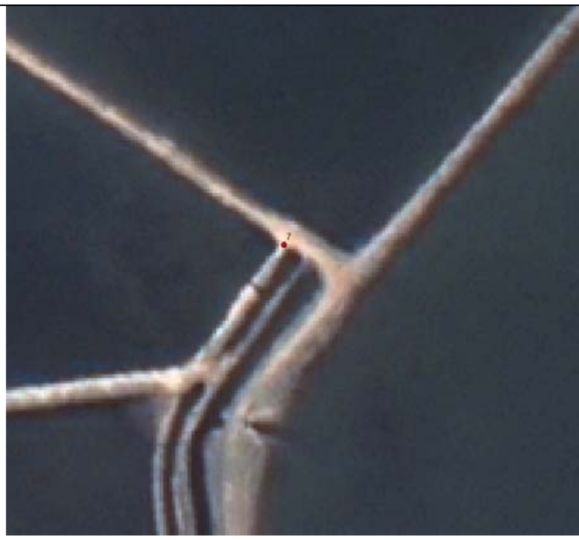
Point Number	X[m]	Y[m]	Orthom. Height [m]
7	516323.03	679956.05	1.70

UTM zone 44 North Ellipsoid wgs84

Description

Intersection at dickes of salt ponds.3.1 km from base-station.

Images



Point 8B

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
8B	N 6°16'53.66090"	E 81°18'02.37176"	-82.224

Lat/long Ellipsoid wgs84

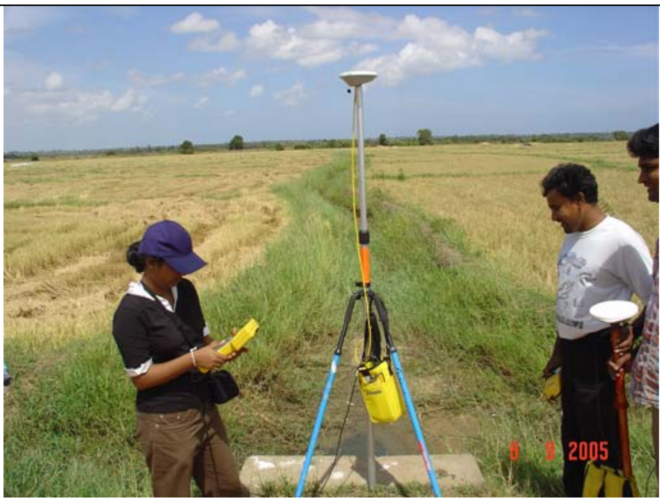
Point Number	X[m]	Y[m]	Orthom. Height [m]
8B	533256.42	694339.91	14.49

UTM zone 44 North Ellipsoid wgs84

Description

Intersection between road and ditch. 25 km from basestation.

Images



Point 9

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
9	N 6°12'44.75676"	E 81°18'07.16274"	-92.467

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
9	533408.01	686696.93	4.63

UTM zone 44 North Ellipsoid wgs84

Description

Intersection road/ditch. Approx. 21.5 km from basestation

Images

Point 10

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
10	N 6°15'25.12527"	E 81°23'13.93788"	-94.147

Lat/long Ellipsoid wgs84

Point Number	X[m]	Y[m]	Orthom. Height [m]
10	542831.58	691627.52	2.88

UTM zone 44 North Ellipsoid wgs84

Description

Corner of salt-lake. Approx 31 km from reference station

Images

Point 11

Coordinate position

Point Number	Latitude	Longitude	Ellips. Height [m]
11	N 6°17'13.73290"	E 81°23'04.57902"	-87.963

Lat/long Ellipsoid wgs84

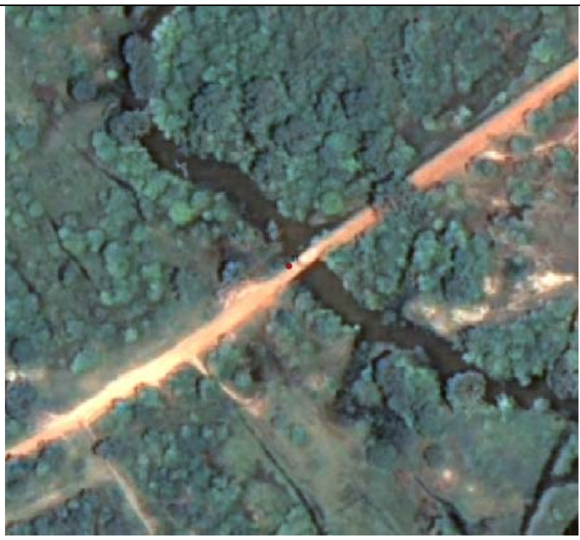
Point Number	X[m]	Y[m]	Orthom. Height [m]
11	542541.56	694962.34	8.89

UTM zone 44 North Ellipsoid wgs84

Description

Intersection brigde/river. Approx. 32 km from reference.

Images



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